



Environment
Canada

Environnement
Canada

00503900 DEST PVM
TP 360 E5713

EXCH

COPY 03

VOL

ISS 198

ENFOR PROJECT P

ENFOR Project P-198

Uses of Nitrogen Fixation and
Other Root Symbioses for
Biomass Production

by

J. André Fortin

Énergie
ENFOR
de la Forêt

Energy
ENFOR
from the
Forest

Énergie
ENFOR
de la Forêt

Energy
ENFOR
from the
Forest

Énergie
ENFOR
de la Forêt

Energy
ENFOR
from the
Forest

Énergie
ENFOR
de la Forêt

Energy
ENFOR
from the
Forest

Énergie
ENFOR
de la Forêt

Energy
ENFOR
from the
Forest

Énergie
ENFOR
de la Forêt

Energy
ENFOR
from the
Forest

Contractor's Progress Report^{1/}
DSS Contract 42SS.KL011-1-0020

ENFOR Project P-198

Uses of Nitrogen Fixation and
Other Root Symbioses for
Biomass Production

by

J. André Fortin

Contractor: Université Laval
Pavillon de l'Education
Cité Universitaire
Ste. Foy, Québec
G1K 7P4

Scientific Authority:

Dr. L. Chaterpaul
Canadian Forestry Service
Environment Canada
Petawawa National Forestry Institute
Chalk River, Ontario
K0J 1J0

^{1/} This report has been reviewed by the Canadian Forestry Service and approved for distribution. Approval does not necessarily signify that the contents reflect the views and policies of the Canadian Forestry Service. Mention of trade names or commercial products does not constitute recommendation or endorsement for use.

October 1982

This work was carried out with funds provided by the Canadian Forestry Service's ENFOR Contract P-198 for the 1981 - 1983 period, administered by the federal Department of Supply and Services.

The Canadian Forestry Service's Scientific Authorities for this work are:

1 April 1980 to Dec. 30 1981

Dr. A. Carlisle,
Senior Scientist,
Petawawa National Forestry Institute,
Chalk River, Ontario,
K0J 1J0

1 Jan. 1982 to 31 March 1983

Dr. L. Chatarpaul,
Project Leader,
Petawawa National Forestry Institute,
Chalk River, Ontario,
K0J 1J0

(Tel.: 613-589-2880)

TABLE OF CONTENTS

	Page
1. INTRODUCTION.....	1
2. ESTABLISHMENT AND DEFINITION OF EXPERIMENTAL PLOTS TO ASSESS EFFECTS OF ALDER ON OTHER TREE SPECIES AND ON THE SOIL	2
2.1 Objectives	2
2.2 History of the establishment of the plantations	2
2.2.1 Sites	3
2.2.2 Tree Species	3
2.2.3 Treatments	3
2.3 Report on work carried out in 1981 - 1982	5
2.3.1 Plant Propagation	5
2.3.2 Location of Plantations	7
2.3.3 The State of the Plantations in the Spring of 1981	7
2.3.4 Insects and Diseases Present in the Plantations in 1981	13
2.3.5 The Physical and Chemical Characteristics of the Soils of the Experimental Plantations	14
2.3.6 Preliminary Results of Research of the Leaf Characteristics of Hybrid Poplar, <u>Alnus glutinosa</u> and Willow (<u>Salix alba</u> and <u>S. nigra</u>)	17
2.4 Work in the 1982 - 1983 Period	34
3. <u>FRANKIA</u> STRAIN SELECTION	34
4. <u>FRANKIA</u> INOCULUM PRODUCTION AND APPLICATION	40
5. SELECTION OF SUPERIOR MYCORRHIZAL SYMBIONTS ON WILLOWS, ALDERS AND POPLARS	40
6. GROWTH AND SURVIVAL OF DIFFERENT PROVENANCES OF <u>ALNUS</u> <u>GLUTINOSA</u>	43
6.1 The Seed	43
6.2 Characteristics of the Experimental Site	45
6.3 Treatment of Seeds and Seedlings	45
6.4 Seed Germination	46
6.5 Treatment after Germination	48
6.6 Survival of the Shaded Plants	48
6.7 Growth of the Seedlings	48
6.8 Proposed Work	51

	Page
7. TRANSFER OF FIXED NITROGEN FROM ONE TREE SPECIES TO ANOTHER BY COMMON ECTOMYCORRHIZAL MYCELIA	54
8. THE CYCLING OF NITROGEN AT DIFFERENT TREE SPACINGS	56
8.1 Introduction	56
8.2 The Objective	56
8.3 Tree Species Used in the Experiment	56
8.4 Experiment Design	57
8.5 Planting the Experiment	57
8.6 Soil Sampling and Analysis	57
8.7 Weed Control and Plant Replacement	72
8.8 Installation of Tension Lysimeters	72
8.9 Proposed Work 1982	75
9. ALLELOPATHIC INTERACTIONS BETWEEN ALDER, POPLAR AND <u>FRANKIA</u> ...	75
9.1 Allelopathic Substances of Balsam Poplar (<u>Populus balsamifera</u>) and the Germination of <u>Alnus crispa</u> Seeds ...	76
9.2 Allelopathic Substances of Balsam Poplar and the Development of Nodulated and Non-Nodulated seedlings of <u>Alnus crispa</u>	76
9.3 Identification of the Poplar Leachates	77
9.4 Effects of Endogenous Phenols in the Alder on the Activity of <u>Frankia</u>	78
10. SURVIVAL OF <u>FRANKIA</u> SYMBIONTS IN THE FIELD	79
10.1 Tree and Shrub Species	79
10.2 <u>Frankia</u> Inoculation	81
10.3 Inoculated Plant Performance	81
10.4 Work for 1982	83
11. SCIENTIFIC OUTPUT FROM THE ENFOR CONTRACTS	83
11.1 Tangible Productivity	83
11.2 Intangible Productivity	89

TABLES

	Page
Table 1 Characteristics of Plants Produced for planting in the Spring and Summer of 1980	4
Table 2 Characteristics of Plants Produced for planting in the Spring of 1981	6
Table 3 Location and Characteristics of the Experimental Plantations	9
Table 4 Mortality One Year After Planting	12
Table 5 Methods Used to Analyse the Soil	15
Table 6 Average Physical Characteristics of Soils in the Experimental Blocks	16
Table 7 Average Chemical Characteristics of Soils in the Experimental Blocks	18
Table 8 Physical Characteristics and Cation Exchange Capacity of the Soils in the Experimental Plots	19
Table 9.1 - 9.13 Chemical Composition of the Soils in each Experimental Plot	20-32
Table 10 Methods of Leaf Analysis	33
Table 11 Leaf Characteristics of Hybrid Poplar	35
Table 12 Leaf Characteristics of <u>Salix alba</u>	36
Table 13 Leaf Characteristics of <u>Alnus glutinosa</u>	37
Table 14 Location of <u>Frankia</u> Provenances	38
Table 15 Formation of Ectomycorrhizae on <u>Alnus rugosa</u> , <u>A. crispa</u> var. <u>mollis</u> and <u>Populus tremuloides</u> by Different Species of Fungus	42
Table 16 Location of the <u>Alnus glutinosa</u> Provenances Used in the Experiment	44
Table 17 Germination of Alder Seed	47
Table 18 Alder Seedling Mortality	49
Table 19 Height of <u>Alnus glutinosa</u> After 11 Weeks of Growth	50

	page
Table 20 Provenances from Dr. Weissgerber's Seed Bank in Germany	52
Table 21 Banks of Seed of Alder Provenances (<u>Alnus glutinosa</u>)	53
Table 22 Characteristics of the Plants Produced	58
Table 23 Mortality of Poplar and Alder in the Experiment	73
Table 24 The Alder and <u>Elaeagnus</u> Species Used in the Experiment ..	80
Table 25 Provenances of Alder and <u>Elaeagnus</u>	80
Table 26 Alder Seedling Inventory - Petawawa NFI, Ontario, Summer 1981	82
Table 27 Graduate Studies Associated with the ENFOR P-198 project	85
Table 28 Publications from the ENFOR P-198 program	86
Table 29 Invited Conference Papers Associated with the ENFOR project	87
Table 30 Conference Papers with Abstracts Associated with the ENFOR P-198 project	88

FIGURES

	page
Figure 1 Map showing the location of the experimental plantations	8
Figure 2 Plan of final design at Amos	10
Figure 3 The complete layout	59
Figure 4-15 Spacings and densities of poplars and alders	60-71
Figure 16 The modified design	74

USES FOR NITROGEN FIXATION
AND OTHER ROOT SYMBIOSES
FOR BIOMASS PRODUCTION

A progress report
for 1981-82
by
J. ANDRE FORTIN

1. INTRODUCTION

This interim report describes the work done to fulfill the first part of the ENFOR PROJECT P-198 contract. This contract is between Laval University and Federal Government Canada and extends over a period of 2 years, 1981 - 1983.

The work is a continuation of earlier work on nitrogen fixation and other root symbioses in relation to biomass production carried out under ENFOR contracts P-9 and P-78 in the 1978 - 1981 period. This work has been described in previous ENFOR reports (Fortin, J.A. 1979. Forest utilization for Energy and the Role of Nitrogen Fixation; Fortin, J.A. 1981. Uses of nitrogen fixation and other root symbioses for biomass production. Progress Reports 1979 - 1980, 1980 - 1981 ENFOR P-78 reports).

This progress report describes the work done in the 1981 - 1982 period. The final synthesis of all the work will be issued at the end of the 1982 - 1983 contract period.

The objective of the research is to examine ways of using nitrogen fixation and mycorrhizal symbioses in intensively managed forests to

increase biomass production and maintain soil fertility with minimal use of energy-demanding fertilizers.

In order to achieve this objective it is necessary to study and understand the organisms and the processes involved, and their relationship with vegetation and other components of the soil. For example the nitrogen-fixing symbiont on non-leguminous trees and shrubs is Frankia, an actinomycete about which relatively little is known. If the Frankia tree symbiosis is to be manipulated to increase yield and maintain soil fertility a great deal more knowledge is needed.

2. EXPERIMENTAL PLANTATIONS

2.1 Objectives

The experimental plantations were established to examine the use of nitrogen-fixing and mycorrhizal symbioses in intensely managed forests to increase biomass yield and maintain soil fertility.

This report describes the history of the establishment of the plantations and their condition after one year's growth. In particular the report describes the soil characteristics, as well as a preliminary estimate of growth, of biomass, and of concentrations of nutrients in the trees.

2.2 History of the establishment of the plantations (Mr. Roland Camirand)

The plantations were established in the 1979 - 1980 and 1980 - 1981 periods at Amos (Abitibi Region), St. Louis (Temiscouata Region) and sites at St. Lambert and Villeroy in the Quebec Region. They consisted of fourteen 0.3 ha plots, including five at Amos, three at St. Louis and six near Quebec City (St. Lambert and Villeroy). The plot layouts are described in the ENFOR progress report for the 1979 - 1980 period.

2.2.1 Sites

The plots covered a range of sites including sandy soils at Villeroy and Amos, agricultural soils at St. Lambert and St. Louis, and a drained peat bog at St. Lambert. The agricultural soils varied from a loam at St. Louis to a poorly drained heavy loam at St. Lambert. A more detailed description of the areas and the site preparation are given in the ENFOR progress report for the 1979 - 1980 period.

2.2.2 Tree Species

The tree species used at these sites included Alnus crispa, A. rugosa, A. glutinosa, Populus hybrids, P. balsamifera, P. tremuloides, Salix alba, Salix nigra and Pinus banksiana. The Alnus crispa and A. rugosa were grown from seed, the A. glutinosa from wild-grown seedlings, the Poplar hybrids, Populus balsamifera, Salix alba and Salix nigra from woody cuttings, the Populus tremuloides from seeds. The jack pine (P. banksiana) were 2 - 0 nursery grown plants (Table 1).

With the exception of the jack pine none of the species is commonly used in forestry, and few guidelines were available, so that it was necessary to develop the propagation techniques. The propagation techniques used are given in the ENFOR progress report for the 1979 - 1980 period (see also Table 1).

2.2.3 Treatments

The treatments consisted of:

1. Alnus crispa
2. A. rugosa
3. Populus tremuloides
4. A. crispa x P. tremuloides
5. A. rugosa x P. tremuloides
6. Poplar hybrids (USA M52, M53 clones)

Table 1. Characteristics of plants produced for planting in the spring and summer of 1980

Species	Method of propagation	Provenance	Production method	Date established ^{1/} - Quantity ^{2/}
<u>Populus tremuloides</u>	Seed	Laval University (lots BP, 61) East Angus (lots By, C)	Paper pots (815), Peat: sand 2:1, 15-30-15 Paper pots (815), Peat, 15-30-15	1 (DE) 2520 (A,C,D,E) 2 (AC)
<u>Populus balsamifera</u>	Cuttings	Laval University	Cut in March stored in a trench at 40°C (1-2 weeks)	1 (ABC) 1620 (A,B,C)
<u>Populus x hybrid</u>	Cuttings	Ministry of Energy & Resources Duchessay (MS2, MS3 USA)	Cut in the fall Kept in cold room (4°C)	1 (ABCDE) 5040 (A,B,C,D,E)
<u>Alnus crispa</u>	Seed	Manic 5	Paper pots (50842), Peat: sand 2:1, 15-30-15 Frankia in Crone's solution	1 (D) 4320 (A,B,C,D) 2 (ABC)
<u>Alnus rugosa</u>	Seed	Cap-Rouge (lot 141) Rivière aux Castors	Paper pots (50842), Peat: sand 2:1, 15-30-14 Frankia in Crone's solution	1 (D) 3420 (A,C,D) 2 (AC)
<u>Alnus glutinosa</u>	Wild	Arboretum at Villeroy	Cut in spring Stored in a trench at 4°C (1-2 weeks)	1 (ABC) 1620 (A,B,C)
<u>Salix alba</u>	Cuttings	Ministry of Energy & Resources (5018, 5020, 5022, 5023)	Cut in the fall Stored in a refrigerator at < 0°C	1 (ABCD) 3240 (A,B,C,D)
<u>Salix nigra</u>	Cuttings	Ministry of Energy & Resources (5012, 5013, 5015)	Cut in the fall Stored in a refrigerator at < 0°C	1 (E) 1800 (E)
<u>Pinus banksiana</u>	Seed	Nursery St. Modeste (2-0) Laval University (3 months)	Paper pots (50842), Peat: sand 2:1, 15-30-15	1 (DE) 1080 (D) 1800 (E)

1 Date of planting in the field: 1= mid-May to early June, 2= Early to mid-August

2 Site of plantations: A= St. Lambert, B= St. Lambert (peat bog), C= Villeroy, D= St. Louis du Ha: Ha:, E= Amos

7. A. crispa x Poplar hybrids
8. A. rugosa x Poplar hybrids
9. Salix (Clones No. 5012, 5013, 5015, 5018, 5020, 5022, 5023)
10. A. crispa x Salix
11. A. rugosa x Salix
12. Pinus banksiana
13. A. crispa x P. banksiana
14. A. rugosa x P. banksiana
15. Control (weeds controlled)
16. Control (untreated)
17. P. balsamifera
18. A. glutinosa x P. balsamifera
19. A. glutinosa

In each plot there were two replicates of each treatment.

2.3 Report on work carried out in 1981 - 1982

2.3.1 Plant Propagation

The propagation of plants has been by seed, cuttings or wild plants. The provenance and the methods of propagation and culture are described for each species in Table 2.

It is clear that variation in origin, propagation production and establishment date will have to be taken into account in subsequent analysis and interpretation of results.

Production problems of plants raised in the winter of 1981 reduced the number of trees available for planting. During the same spring some of the plants were replaced. Details of plant establishment are summarised in Table 2.

Table 2. Characteristics of plants produced for planting in the spring of 1981

Species	Number		Characteristics
	Planting	Mortality	
<u>Populus tremuloides</u>		668 ¹	Seed; production (winter 1981). Styroblocks
<u>Populus balsamifera</u>	1080		Cuttings; production (winter 1981). Styroblocks
<u>Populus X hybrid</u> (M52 - M53)		438	Nursery; cutting beds (summer 1980)
<u>Alnus crispa</u>	4320	1722	4320 Seed; production (winter 1980). Styroblocks 1722 Seed; production (spring 1980). Peat pots
<u>Alnus rugosa</u>		997	Seed; production (spring 1980), peat pots.
<u>Alnus glutinosa</u>		361	Wild plants; 1 - 2 years old
<u>Salix alba</u>		617	Nursery; cutting beds (summer 1980)
<u>Salix nigra</u>		146	Nursery; cutting beds. (summer 1980)
<u>Pinus banksiana</u>		1016	Seed; production (winter 1981). Peat pots

1. Replacement of the trembling aspen has not been carried out in the Amos plantation (1390 plants). Poor production in the winter of 1981.

2.3.2 Location of the plantations

The fourteen blocks of experimental plots are located in three regions in the province of Quebec as described earlier: the Quebec Region (6), the Temiscouata Region (3) and the Abitibi Region (5). Each block has an area of 0.3 ha (52.8 x 57.6 m) and consists of 32 plots (each 13.2 x 7.2 m) with or without mixed or pure plantation, and with or without site treatment (Figure 1).

In the mixed plantations the rows of nitrogen-fixing and non-fixing companion species were planted alternately 1.2 m apart with 60 cm between the plants. The plots were 2.4 m apart.

All sites were ploughed and harrowed. The treatment of the different areas is described in Table 3.

2.3.3 The state of the plantations in the spring of 1981

It is difficult to draw any firm conclusions only one year after establishment of the trees in the field plots. However, it is already clear that the heavy mortality in some plots will be a constraint upon the experiment.

Alnus rugosa is biologically difficult to propagate, resulting in limited availability of plants of this species. This has resulted in the elimination of this species of alder from the Amos site, and the reduction of the block to permit completion of the rest of the plantings with other tree species. Figure 2 illustrates the final disposition of the Amos blocks.

The trembling aspen (Populus tremuloides) experienced establishment losses and was severely attacked by insects and diseases,

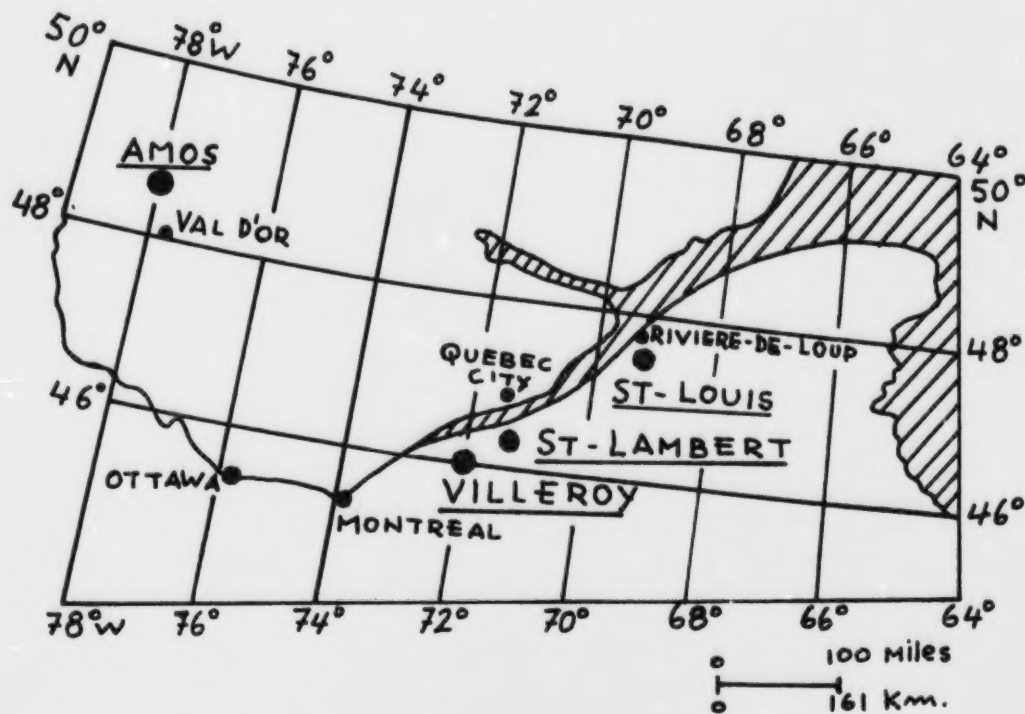


Figure 1 Location of Experimental Plantations at Amos, Villeroy, St. Lambert and St. Louis.

Table 3 Location and characteristics of the experimental plantations

Region	Location	Plot No.	Site	Site Preparation
1- Quebec	St.Lambert	1-1-00 1-2-00	Poorly drained heavy loam soil on an agricultural site	Ploughed, harrowed, "Round up" treated
1- Quebec	St.Lambert	1-3-00 1-4-00	Peat bog	Deep ploughed, harrowed drained, chalk scattered
1- Quebec	Villeroy	1-5-00 1-6-00	Forest regeneration, well-drained sandy soil	Ploughed, harrowed, bulldozed
2- Temiscouata	St.Louis	2-1-00 2-2-00	Loamy soil. Previously farm (3-4 years); drainage gradient.	Ploughed and harrowed
3- Abitibi	Amos	3-1-00 3-2-00 3-3-00 3-4-00 3-5-00	Abandoned agricultural soil and forest regeneration. Gradient from well drained sandy soil to poorly drained clay loam	Ploughed, harrowed, forest regeneration bulldozed

Note: Tree species used and a key to the Plot Numbers are given in the progress report for the ENFOR P-78 project for the 1980 - 1981 period, pages 4 - 18.

3-1-8	3-1-7		
3-1-9	3-1-1		
3-1-25	3-1-17		
3-1-26	3-1-18	3-1-10	3-1-2
3-1-27	3-1-19	3-1-11	3-1-3
3-1-28	3-1-20	3-1-12	3-1-4
3-1-29	3-1-21	3-1-13	3-1-5
3-1-30	3-1-22	3-1-14	3-1-6
3-1-31	3-1-23	3-1-15	
3-1-32	3-1-24	3-1-16	
	3-2-17	3-2-9	
3-2-26	3-2-18	3-2-10	
3-2-27	3-2-19	3-2-11	
3-2-28	3-2-20	3-2-12	3-2-4
3-2-29	3-2-21	3-2-13	3-2-5
3-2-30	3-2-22	3-2-14	3-2-6
3-2-31	3-2-23	3-2-15	3-2-7
3-2-32	3-2-24	3-2-16	3-2-8
3-3-25	3-3-17	3-3-9	3-3-1
3-3-26	3-3-18	3-3-10	3-3-2
3-3-27	3-3-19	3-3-11	3-3-3
3-3-28	3-3-20	3-3-12	3-3-4
3-3-29	3-3-21	3-3-13	3-3-5
3-3-30	3-3-22	3-3-14	3-3-6
3-3-31	3-3-23	3-3-15	3-3-7
3-3-32	3-3-24	3-3-16	3-3-8
3-4-25	3-4-17	3-4-9	3-4-1
3-4-26	3-4-18	3-4-10	3-4-2
3-4-27	3-4-19	3-4-11	3-4-3
3-4-28	3-4-20	3-4-12	3-4-4
3-4-29	3-4-21	3-4-13	3-4-5
3-4-30	3-4-22	3-4-14	3-4-6
3-4-31	3-4-23	3-4-15	3-4-7
3-4-32	3-4-24	3-4-16	3-4-8

AMOS
LA FERME
BLOCS: 3-1-00
3-2-00
3-3-00
3-4-00

3-2-1
3-2-2
3-2-3

3-2-25

Note: Treatments associated with the numerical codes in this figure are defined in the progress report of the ENFOR P-78 project for the year 1980 - 1981 on pages 4 and 14 - 18.

Figure 2. Plan of final design at Amos

particularly in the Quebec region. Elsewhere in this report Dr. Michel Dessureault summarizes the details of these attacks and the conclusions concerning tree growth.

In addition, a late spring frost in the spring of 1980 virtually eliminated the trembling aspen at the Amos site. All the problems with this species, indicate that the plants should not be replaced.

Table 4 summarizes the results from the survival assessments made in the spring of 1981. All the missing plants were replaced during the months of May and June 1981. Mortality was high (63%) in the jack pine at Amos due to the plants used at this site being too young for planting out (see Table 1). The highest mortality (97%) was in the Amos aspen for the reasons described earlier. On some sites alder losses were considerable (Villeroy 22% to 49%; St. Lambert 19% to 44%; St. Louis 30% to 59%). Hybrid poplar losses were relatively small (4% to 21%). Willows survived quite well except for 37% losses at St. Louis.

The main cause of plant failure was the planting shock associated with the change in environment, but weed competition (mainly at St. Louis and Amos), lifting of tree roots by frost (at the Villeroy site) and the formation of natural drainage channels in the spring (at the St. Lambert and Amos sites) also accounted for some of the losses.

There were problems of soil nutrient levels in the peat bog at St. Lambert. In order to obtain normal tree nutrition it will be necessary to add fertilizers, which is contrary to the research objective of these studies. It may be desirable to eliminate the peat site from the present research project and study the effects of fertilization separately.

Table 4 Mortality one year after planting

Species	Villeroy No. (%)	St Lambert No. (%)	St Louis No. (%)	Amos No. (%)	Total No	Comments
<u>Populus tremuloides</u>	115 (16)	271 (38)	282 (26)	1390 (97)	2058	Amos - frosted after planting, spring 1980
<u>Populus balsamifera</u>	*	*	—	—	—	
<u>Populus X hybrid</u> (M52, M53)	29 (4)	50 (7)	54 (5)	305 (21)	438	
<u>Alnus crispa</u>	368 (41)	394 (44)	960 (59)	**	1722	
<u>Alnus rugosa</u>	195 (22)	322 (36)	480 (30)	**	997	
<u>Alnus glutinosa</u>	264 (49)	97 (18)	—	—	361	
<u>Salix alba</u>	125 (17)	90 (12)	402 (37)	—	617	
<u>Salix nigra</u>	—	—	—	146 (10)	146	
<u>Pinus banksiana</u>	—	—	102 (9)	914 (63)	1016	Plants too young; frost

* Planted in spring 1981 - very good recovery. (Mortality 5 - 10%)

**Planted in spring 1981 - all sites with Alnus crispa - excellent recovery. (Mortality about 5%)

After maintaining these experimental plantations for two summers, it is apparent that a great deal of manpower and money has been expended on mechanical weed control. Weed control is a major constraint and considering the other establishment problems, it may be considered desirable to intensify work on a limited number of plots.

The choice of the plots will depend upon mortality, soil drainage, etc., treatment and the number of homogenous replicates available. The selection of plots for intensive study will need to be made in the spring of 1982.

2.3.4 Insects and Diseases Present in the Plantations in 1981
(Dr. Michel Dessureault)

Two diseases and several insects were observed in the mixed plantations at Villeroy when they were visited in late September 1981.

In spite of the abundance and diversity of tree parasites in some parts of the plantations, Alnus rugosa and A. glutinosa were not affected at all, but the A. crispa was locally severely attacked by the alder saw-fly.

The willow had been attacked by the imported willow leaf-beetle (Plagioderma versicolor (Laich.)), and the willow flea-beetle (Orchestes rufipes Lec.).

The hybrid poplars were severely infected by a leaf rust. It is known that some hybrids are more susceptible to rust than others. This disease will probably affect growth, but its real impact is not known. The balsam poplar was attacked by an aphid which produced a blackish crust on the leaves causing them to roll inwards.

Of all the species present the trembling aspen was most affected by a combination of aphids, willow flea-beetle, and shoot burn.

A great majority of the young plants were completely defoliated and it is not likely that they will survive. The shoot burn attacks the tender tissues of the first year's shoots. If the young plants are not killed, then growth will be seriously reduced. In this case it is difficult to distinguish the effects of the disease from those of the insects.

All the entomological and pathological conditions encountered in this plantation are considered as marginal. Their presence is accounted for by the state of the vegetation surrounding the plantation. It would be unrealistic to carry out even a chemical control, because the effects are likely to be very hazardous.

If the shoot burn makes it impossible to establish trembling aspen on this site, it will be necessary to find out whether or not the plants used in the experiment were genotypes that are particularly sensitive to the disease.

(Note. The entomology and pathology services of the M.E.R. identified some of the insects found in the plantation).

2.3.5 The Physical and Chemical Characteristics of the Soils of the Experimental Plantations (Dr. Yvon Laflamme)

The soils of the plantations were analysed by the methods described in Table 5. The physical characteristics (Table 6) varied considerably from one site to another.

The data illustrate the very sandy nature of the soil in block 1.5 at Villeroy (84% sand), and blocks 3.1 and 3.2 at Amos (88% and 81% sand respectively). Variation within blocks was generally fairly low for this characteristic, except at Amos 3.3 and 3.4.

The clay content varied from 5% at Villeroy to 23% at Amos block 3.4.

Table 5 Methods used to analyse the soil

Parameter	Method	References
1. <u>Soil physics</u>		
Soil particle size	Densimeter (hydrometer)	Bouyoucos, 1962 (1)
2. <u>Chemistry</u>		
Acidity (pH)	Mineral soil: soil/CaCl ₂ solution - 0.01M: 1/2.5 Organic soil: soil/CaCl ₂ solution - 0.01M: 1/5	Peech, 1965 (2)
Organic carbon	Mineral soil: oxidation by dichromate	Walkley and Black, 1934 (3)
Total nitrogen	Macro Kjeldahl	Bremner, 1960 (4)
Available phosphorus	Extraction: Truog - 1	Truog, 1930 (5)
Exchangeable cations (K, Mg, Ca)	Extraction: Ammonium acetate (1N - pH 7.0) Determination: Atomic absorption	Chapman, 1965a (6)
Cation exchange capacity	Ammonium acetate (1N - pH 7.0)	Chapman, 1965b (7)
(1) Bouyoucos, G.L. 1962. Agron. J. 54: 464-465. (2) Peech, M. 1965. In: C.A. Black (ed.), Methods of soil analysis.: 914-926. (3) Walkley, A. & Black, I.A. 1934. Soil Sci. 37: 29-38. (4) Bremner, J.M. 1960. J. Agric. Sci. 55: 11-14. (5) Truog, E. 1930. J. Amer. Soc. Agron. 22: 874-882. (6) Chapman, H.D. 1965a. In: C.A. Black (ed.), Methods of soil analysis: 891-901. (7) Chapman, H.D. 1965b. " " " " " " : 902-904.		

Table 6 Average physical characteristics of soils in the experimental blocks^{1/}

Block	%				Texture Class ^{2/}
	Sand	Coarse silt	Fine silt	Clay	
St. Lambert					
1.1	47 ^{3/}	(12) ^{4/}	22 (14)	18 (19)	Loam
1.2	43	(27)	24 (23)	19 (21)	Loam
St. Lambert Peat Bog					
1.3	-	-	-	-	-
1.4	-	-	-	-	-
Villeroy					
1.5	84	(3)	5 (40)	5 (22)	Loamy sand
1.6	83	(2)	6 (10)	5 (10)	Loamy sand
St. Louis					
2.1	48	(7)	21 (16)	20 (8)	Loam
2.2	51	(3)	18 (5)	19 (6)	Loam
2.3	48	(2)	20 (6)	20 (0)	Loam
Amos					
3.1	88	(1)	3 (18)	6 (9)	Loamy sand
3.2	81	(17)	5 (92)	8 (43)	Loamy sand
3.3	51	(43)	14 (59)	21 (26)	Loam
3.4	40	(35)	18 (32)	23 (12)	Loam

1. Mean of 4 plots per block with the exception of block 2.3 (3 plots)

2. Canadian System of Soil Classification

3. Mean

4. Coefficient of variation %

The pH of the soils varied from 4.4 at Villeroy, to 5.3 in Amos blocks 3.1 and 3.4. Coefficients of variation were low, 10% or less. Total nitrogen was lowest in the Amos blocks (0.06 to 0.12%) and highest in the St. Lambert peat bog (1.16% to 1.28%). The most variation was at Amos (coefficients of variation 23% to 38%) (Table 7).

As would be expected, the cation exchange capacity was very high (64.6 to 79.0 meq/100g) at the St. Lambert peat bog, and very low in the most sandy blocks 3.1 and 3.2 at Amos (Table 7).

Available phosphorus was very variable, ranging from 27 to 30 ppm on the St. Lambert peat site to 126 ppm at Amos. On the latter site coefficients of variability were high (up to 81%) (Table 7).

The potassium levels were low on the St. Lambert 1.1 and 1.2 blocks (29 to 34 ppm) as well as at Villeroy (23 to 25 ppm) and Amos (31 to 56 ppm). Magnesium levels at Villeroy were very low at 14 to 17 ppm. The magnesium and calcium levels on the St. Lambert peat site are very high, resulting from the dolomite application two years before the experiment (Table 7).

The detailed physical and chemical characteristics of the soils of the experimental plots are listed in Tables 8 and 9.1 - 9.13.

2.3.6 Preliminary Results of Research on the Leaf Characteristics of Hybrid Poplar, Alnus glutinosa and willow (Salix alba, S. nigra) (Mr. R. Camirand)

The methods used to analyse the leaves of hybrid poplar, willow and alder are described in Table 10. The leaves were dried at 65°C for 48 hours and ground to pass a 20 mesh sieve. The micro Kjeldahl method was used for nitrogen, the bases were analysed using atomic absorption, and phosphorus assessed using phosphovanadomolybdic acid.

Table 7 Average chemical characteristics of soils in the experimental blocks 1/

Block	pH (CaCl ₂)	Organic carbon	Total Nitrogen	CEC meq/100g	ppm			
					Available Phosphorus	Exchangeable Potassium	Exchangeable Magnesium	Exchangeable Calcium
St-Lambert								
1.1	5.0 (7)	1.6 (28)	0.12 (23)	8.9 (32)	69 (69)	29 (14)	93 (66)	413 (26)
1.2	4.8 (6)	2.3 (21)	0.15 (19)	13.1 (27)	37 (98)	34 (22)	52 (77)	460 (37)
Tourbière								
1.3	4.9 (10)	49.2 (9)	1.16 (12)	64.6 (34)	30 (11)	94 (25)	386 (9)	15406 (36)
1.4	4.5 (9)	52.2 (4)	1.28 (7)	79.0 (9)	27 (17)	126 (26)	261 (10)	12279 (38)
Villeroy								
1.5	4.4 (2)	1.8 (23)	0.10 (22)	15.9 (26)	54 (30)	23 (35)	14 (28)	113 (27)
1.6	4.4 (2)	2.3 (25)	0.11 (22)	18.2 (19)	106 (23)	25 (30)	17 (33)	109 (23)
St-Louis								
2.1	4.6 (2)	3.6 (13)	0.19 (11)	16.7 (49)	91 (21)	116 (17)	100 (31)	905 (24)
2.2	4.7 (3)	4.3 (23)	0.19 (19)	18.7 (31)	111 (21)	109 (14)	136 (22)	804 (43)
2.3	4.7 (4)	5.0 (17)	0.20 (12)	17.4 (36)	79 (25)	84 (20)	124 (29)	1071 (59)
Neos								
3.1	5.3 (9)	1.0 (38)	0.06 (36)	5.4 (32)	55 (60)	31 (18)	17 (29)	474 (53)
3.2	4.9 (7)	1.8 (43)	0.08 (38)	5.6 (24)	52 (73)	39 (39)	49 (58)	618 (37)
3.3	4.8 (6)	2.9 (25)	0.12 (23)	14.8 (21)	55 (81)	41 (22)	108 (44)	775 (34)
3.4	5.3 (7)	2.2 (39)	0.10 (36)	14.1 (35)	126 (39)	56 (25)	202 (22)	1315 (23)

1. Mean of 32 plots per block with the exception of cation exchange capacity (3 plots in block 2.3), 4 plots (other blocks)

2. Mean

3. Coefficient of variation 1.

Table 8 Physical characteristics and cation exchange capacity of the soils in the experimental plots.

Sample	Sand (%)	Coarse silt (%)	Fine silt (%)	Clay (%)	CEC (Me/100 g)
1-1- 6-1	50	14	19	17	10,0
1-1- 8-1	44	12	22	22	12,4
1-1-17-1	54	12	20	14	6,0
1-1-24-1	42	14	26	18	7,3
1-2- 6-1	47	13	20	20	11,9
1-2-12-1	34	16	28	22	13,8
1-2-17-1	34	16	30	20	9,2
1-2-20-1	58	10	19	13	17,6
1-5- 8-1	84	6	6	4	15,8
1-5-13-1	82	6	6	6	17,4
1-5-22-1	84	6	6	4	20,2
1-5-27-1	88	6	2	4	10,2
1-6- 4-1	82	6	6	6	22,0
1-6-12-1	86	4	5	5	17,4
1-6-17-1	82	6	6	6	19,4
1-6-28-1	84	6	5	5	14,0
2-1- 4-1	44	8	26	22	26,3
2-1-10-1	48	12	20	20	9,8
2-1-19-1	52	12	18	18	20,7
2-1-31-1	46	13	21	20	10,0
2-2- 3-1	52	12	18	18	13,2
2-2-14-1	53	11	18	18	24,6
2-2-23-1	49	12	19	20	22,8
2-2-26-1	51	12	17	20	14,2
2-3- 7-1	47	12	21	20	16,1
2-3-14-1	47	14	19	20	27,7
2-3-18-1	49	12	19	20	8,4
3-1- 7-1	89	2	2	7	1,9
3-1-11-1	87	3	3	7	8,8
3-1-18-1	89	2	3	6	5,8
3-1-25-1	87	4	3	6	5,2
3-2- 4-1	87	3	3	7	4,0
3-2-12-1	85	4	4	7	5,4
3-2-25-1	90	3	1	6	7,2
3-2-30-1	61	14	11	14	5,9
3-3-16-1	43	16	17	24	16,6
3-3-18-1	80	3	4	13	10,8
3-3-24-1	28	23	24	25	17,8
3-3-28-1	52	15	12	21	14,0
3-4- 3-1	61	10	10	19	15,8
3-4- 8-1	33	20	22	25	13,9
3-4-11-1	39	19	18	24	7,4
3-4-19-1	29	26	23	22	19,3

Note: Sample codes are defined in the 1980 - 1981 EMPOR P-78 report.

Table 9.1: Soil chemical composition for each individual sub-plot of
St.Lambert Station, plot #1.1.

20.

Sample	pH	<u>N</u> %	<u>P</u> ppm	<u>K</u> ppm	<u>Mg</u> ppm	<u>Ca</u> ppm	<u>Org. C</u> %
1-1- 1-1	4,60	0,118	42,8	26	67	433	1,54
1-1- 2-1	4,70	0,119	52,0	30	94	428	1,66
1-1- 3-1	4,90	0,137	96,2	33	158	531	1,90
1-1- 4-1	5,15	0,140	121,7	30	200	537	1,78
1-1- 5-1	4,95	0,131	40,6	30	84	376	1,56
1-1- 6-1	4,70	0,141	19,4	35	46	342	1,87
1-1- 7-1	4,60	0,150	40,3	29	99	359	2,17
1-1- 8-1	4,50	0,156	45,8	37	68	342	2,42
1-1- 9-1	4,70	0,083	55,1	28	61	248	1,07
1-1-10-1	4,80	0,083	105,0	20	86	238	1,12
1-1-11-1	5,70	0,085	119,7	26	196	422	1,00
1-1-12-1	6,00	0,069	213,5	29	234	410	0,63
1-1-13-1	5,40	0,091	78,1	28	159	416	1,09
1-1-14-1	5,10	0,090	46,2	29	73	279	1,19
1-1-15-1	5,40	0,081	191,6	31	222	445	0,97
1-1-16-1	5,45	0,117	144,7	32	214	525	2,12
1-1-17-1	4,90	0,118	44,9	25	43	463	1,75
1-1-18-1	4,90	0,129	46,6	26	43	494	1,93
1-1-19-1	5,00	0,135	42,4	29	79	500	2,12
1-1-20-1	5,30	0,153	29,1	32	46	760	1,94
1-1-21-1	5,00	0,158	27,2	33	38	488	2,08
1-1-22-1	5,20	0,195	19,4	34	31	537	2,64
1-1-23-1	5,05	0,140	44,2	30	63	359	1,97
1-1-24-1	5,30	0,111	63,2	19	123	506	1,59
1-1-25-1	4,60	0,115	50,6	27	32	238	1,49
1-1-26-1	4,60	0,117	53,9	27	41	310	1,89
1-1-27-1	4,60	0,123	62,9	26	49	332	1,84
1-1-28-1	4,90	0,133	48,5	31	45	376	1,91
1-1-29-1	5,10	0,121	17,3	28	26	305	1,51
1-1-30-1	5,20	0,112	41,8	26	73	416	1,35
1-1-31-1	5,00	0,111	85,5	25	90	433	1,33
1-1-32-1	5,00	0,090	113,2	22	98	365	1,32

Note: Sample codes are defined in the ENFOR P-78 report for 1980-1981.

Table 9.2: Soil chemical composition for each individual sub-plot of St.Lambert Station, plot #1.2.

21.

Sample	pH	$\frac{N}{\%}$	$\frac{P}{ppm}$	$\frac{K}{ppm}$	$\frac{Mg}{ppm}$	$\frac{Ca}{ppm}$	$\frac{Org.C}{\%}$
1-2- 1-1	4,45	0,152	26,6	38	31	248	2,38
1-2- 2-1	4,40	0,158	25,0	33	41	416	2,16
1-2- 3-1	4,30	0,143	21,0	37	41	293	2,42
1-2- 4-1	4,30	0,174	23,5	38	40	353	2,42
1-2- 5-1	4,50	0,183	21,3	40	34	342	2,58
1-2- 6-1	4,80	0,189	14,8	31	25	387	2,65
1-2- 7-1	4,70	0,176	22,8	41	38	410	2,53
1-2- 8-1	4,60	0,179	15,5	36	32	410	2,24
1-2- 9-1	5,20	0,112	145,3	37	147	416	2,01
1-2-10-1	5,10	0,098	142,7	31	156	439	1,67
1-2-11-1	5,00	0,105	93,3	31	139	393	1,36
1-2-12-1	4,65	0,148	49,1	40	47	332	2,14
1-2-13-1	4,70	0,118	38,8	38	31	263	1,63
1-2-14-1	4,80	0,113	25,1	34	33	263	1,48
1-2-15-1	4,75	0,158	30,6	35	43	268	1,85
1-2-16-1	4,80	0,114	39,0	33	60	310	1,44
1-2-17-1	5,20	0,130	99,0	24	151	563	2,02
1-2-18-1	4,85	0,165	64,7	34	83	710	2,76
1-2-19-1	4,90	0,169	24,5	33	26	494	2,55
1-2-20-1	5,45	0,177	21,3	34	27	968	2,53
1-2-21-1	5,10	0,174	15,3	29	21	649	2,72
1-2-22-1	5,20	0,193	15,0	33	22	738	2,90
1-2-23-1	5,05	0,176	15,5	45	47	745	2,37
1-2-24-1	5,25	0,196	15,5	60	48	767	2,76
1-2-25-1	4,60	0,111	66,3	21	58	348	2,08
1-2-26-1	4,55	0,126	30,7	26	48	370	1,94
1-2-27-1	4,60	0,141	21,3	29	33	399	1,84
1-2-28-1	4,70	0,180	9,7	30	22	348	2,88
1-2-29-1	4,85	0,189	5,8	22	16	457	3,21
1-2-30-1	5,00	0,169	11,6	25	23	563	2,85
1-2-31-1	4,60	0,163	7,8	28	34	428	2,19
1-2-32-1	4,90	0,150	17,6	31	52	519	2,05

Table 9.3: Soil chemical composition for each individual sub-plot of Peat Bog Station, plot #1.3. 22.

Sample	pH	<u>N</u> %	<u>P</u> ppm	<u>K</u> ppm	<u>Mg</u> ppm	<u>Ca</u> ppm	<u>Org.C</u> %
1-3- 1-1	5,10	0,93	27,0	72	256	11322	40,3
1-3- 2-1	5,50	0,90	31,4	82	282	14558	40,4
1-3- 3-1	5,10	0,93	29,1	80	296	13138	42,2
1-3- 4-1	5,00	0,99	31,3	72	264	12092	43,9
1-3- 5-1	5,05	1,27	27,6	76	258	12870	47,8
1-3- 6-1	5,00	1,11	26,9	64	268	13346	45,3
1-3- 7-1	5,60	1,13	25,3	60	276	20760	48,5
1-3- 8-1	5,25	1,13	33,1	84	310	18580	46,6
1-3- 9-1	5,85	0,80	33,1	78	316	22520	39,7
1-3-10-1	4,60	1,11	27,3	96	290	12194	51,4
1-3-11-1	4,50	1,09	29,0	104	322	12674	50,3
1-3-12-1	4,40	1,10	27,1	108	304	10510	49,5
1-3-13-1	4,45	1,14	28,5	128	340	12234	51,8
1-3-14-1	3,95	1,25	29,4	120	252	7502	54,3
1-3-15-1	4,40	1,31	31,1	112	280	10118	53,4
1-3-16-1	4,30	1,36	31,1	112	254	8726	53,1
1-3-17-1	4,95	1,07	30,6	70	282	14292	43,2
1-3-18-1	4,75	1,16	29,3	70	298	14830	49,5
1-3-19-1	5,30	1,29	30,6	82	310	21560	50,8
1-3-20-1	5,65	1,26	38,0	68	302	24500	49,0
1-3-21-1	5,25	1,28	28,7	68	272	22200	50,5
1-3-22-1	5,40	1,23	31,0	74	304	26720	51,1
1-3-23-1	4,75	1,24	35,2	84	256	13876	53,2
1-3-24-1	5,15	1,14	25,3	72	290	23500	51,3
1-3-25-1	4,80	1,24	35,1	112	302	13062	51,2
1-3-26-1	4,85	1,27	30,2	128	308	14608	51,2
1-3-27-1	4,50	1,37	25,1	112	252	10380	53,4
1-3-28-1	4,95	1,22	30,8	100	292	20440	50,6
1-3-29-1	4,35	1,26	26,9	126	276	10336	52,7
1-3-30-1	3,90	1,23	29,0	152	252	7016	54,2
1-3-31-1	4,05	1,23	30,8	116	258	9302	53,6
1-3-32-1	5,00	1,22	36,3	112	318	21720	50,8

Table 9.4: Soil chemical composition for each individual sub-plot of
Peat Bog Station, plot #1.4.

23.

Sample	pH	$\frac{N}{\%}$	$\frac{P}{ppm}$	$\frac{K}{ppm}$	$\frac{Mg}{ppm}$	$\frac{Ca}{ppm}$	$\frac{Org.C}{\%}$
1-4- 1-1	4,80	1,39	24,2	62	240	12132	53,1
1-4- 2-1	5,25	1,25	28,9	74	266	20440	49,8
1-4- 3-1	5,00	1,23	29,5	66	261	14768	51,2
1-4- 4-1	5,45	1,19	31,5	78	296	24500	49,2
1-4- 5-1	5,00	1,38	30,8	212	266	13458	51,0
1-4- 6-1	5,10	1,24	26,8	106	302	22040	49,6
1-4- 7-1	4,20	1,30	31,1	112	252	9302	53,7
1-4- 8-1	4,50	1,07	38,7	92	236	11948	43,8
1-4- 9-1	4,30	1,34	30,7	124	234	8814	53,9
1-4-10-1	4,65	1,27	29,0	130	286	14258	52,2
1-4-11-1	4,40	1,38	30,8	146	288	12792	52,0
1-4-12-1	4,60	1,28	29,9	132	250	12154	53,0
1-4-13-1	4,40	1,28	28,1	142	252	9898	53,9
1-4-14-1	4,15	1,27	21,4	146	262	9612	53,0
1-4-15-1	3,80	1,36	24,7	132	228	5356	53,7
1-4-16-1	4,40	1,14	30,6	138	274	12574	52,3
1-4-17-1	4,90	1,23	28,0	84	262	14510	51,4
1-4-18-1	4,20	1,36	23,2	120	236	9258	53,6
1-4-19-1	4,00	1,26	24,8	108	254	8702	54,1
1-4-20-1	4,20	1,34	25,1	148	234	9346	53,7
1-4-21-1	4,35	1,36	19,4	130	230	9258	53,8
1-4-22-1	4,55	1,34	21,2	116	258	10140	53,7
1-4-23-1	4,70	1,36	28,4	122	238	13158	52,9
1-4-24-1	4,70	1,36	24,9	88	248	11970	53,4
1-4-25-1	4,25	1,18	25,3	136	284	11596	52,7
1-4-26-1	4,60	1,17	26,3	142	300	14784	50,1
1-4-27-1	4,10	1,38	22,7	170	266	7458	53,9
1-4-28-1	4,50	1,17	31,0	180	320	13982	50,3
1-4-29-1	4,70	1,20	32,1	146	320	22360	49,2
1-4-30-1	3,90	1,32	18,5	148	246	7348	54,2
1-4-31-1	3,90	1,39	19,6	138	210	6752	54,8
1-4-32-1	4,00	1,28	23,3	152	264	8258	53,9

Table 9.5: Soil chemical composition of each individual sub-plot of Villeroy Station, plot #1.5.

Sample	pH	$\frac{N}{\%}$	$\frac{P}{ppm}$	$\frac{K}{ppm}$	$\frac{Mg}{ppm}$	$\frac{Ca}{ppm}$	$\frac{Org.C}{\%}$
1-5- 1-1	4,20	0,125	36,4	29	15	133	2,48
1-5- 2-1	4,40	0,075	72,0	27	14	116	1,37
1-5- 3-1	4,50	0,076	79,7	37	20	150	1,43
1-5- 4-1	4,40	0,127	43,5	40	24	155	2,21
1-5- 5-1	4,40	0,109	45,6	45	22	155	2,15
1-5- 6-1	4,40	0,098	54,0	23	16	137	1,93
1-5- 7-1	4,30	0,095	60,3	17	11	100	1,83
1-5- 8-1	4,30	0,096	61,0	20	12	112	1,89
1-5- 9-1	4,30	0,107	49,4	24	23	133	2,05
1-5-10-1	4,30	0,111	42,1	18	13	112	2,13
1-5-11-1	4,35	0,112	44,3	26	16	137	2,31
1-5-12-1	4,40	0,101	75,5	19	11	108	1,47
1-5-13-1	4,30	0,118	18,8	23	15	129	2,23
1-5-14-1	4,35	0,112	59,3	26	18	137	2,09
1-5-15-1	4,40	0,082	64,5	27	16	129	1,65
1-5-16-1	4,35	0,095	83,0	17	12	120	1,81
1-5-17-1	4,25	0,111	45,4	36	21	142	2,04
1-5-18-1	4,40	0,103	55,4	25	13	133	1,90
1-5-19-1	4,50	0,104	52,6	28	18	159	2,02
1-5-20-1	4,40	0,108	44,6	22	12	116	2,24
1-5-21-1	4,35	0,104	47,5	17	13	120	1,98
1-5-22-1	4,40	0,112	30,5	24	12	125	2,14
1-5-23-1	4,40	0,110	30,2	21	14	108	2,04
1-5-24-1	4,50	0,076	45,7	15	12	61	1,46
1-5-25-1	4,50	0,070	73,5	17	11	61	1,32
1-5-26-1	4,50	0,067	64,1	12	9	65	1,21
1-5-27-1	4,60	0,047	87,7	26	10	58	0,87
1-5-28-1	4,40	0,082	72,9	13	12	92	1,88
1-5-29-1	4,55	0,039	41,4	10	8	61	0,73
1-5-30-1	4,40	0,112	50,5	17	14	65	2,18
1-5-31-1	4,35	0,100	48,7	14	12	100	2,12
1-5-32-1	4,45	0,082	47,8	19	12	76	1,62

Table 9.6: Soil chemical composition for each individual sub-plot of
Villeroy Station, plot #1,6.

Sample	pH	$\frac{N}{\%}$	$\frac{P}{ppm}$	$\frac{K}{ppm}$	$\frac{Mg}{ppm}$	$\frac{Ca}{ppm}$	$\frac{Org.C}{\%}$
1-6- 1-1	4,35	0,077	131,7	15	11	76	1,61
1-6- 2-1	4,35	0,129	91,0	24	16	80	2,55
1-6- 3-1	4,30	0,101	145,6	18	12	92	2,17
1-6- 4-1	4,60	0,126	81,7	52	31	133	2,56
1-6- 5-1	4,40	0,150	70,6	23	24	137	2,94
1-6- 6-1	4,40	0,115	90,2	16	15	116	2,29
1-6- 7-1	4,35	0,146	78,6	26	17	150	3,13
1-6- 8-1	4,40	0,118	116,5	18	14	108	2,27
1-6- 9-1	4,35	0,106	118,8	20	16	108	2,13
1-6-10-1	4,55	0,118	113,1	28	28	96	2,35
1-6-11-1	4,35	0,111	109,5	24	16	100	2,08
1-6-12-1	4,40	0,104	126,9	19	13	92	2,00
1-6-13-1	4,45	0,079	141,5	18	9	73	1,49
1-6-14-1	4,55	0,098	102,6	23	31	150	2,00
1-6-15-1	4,40	0,106	110,7	25	13	92	2,06
1-6-16-1	4,30	0,155	79,5	31	21	163	3,37
1-6-17-1	4,30	0,123	96,5	43	18	120	2,75
1-6-18-1	4,35	0,126	81,5	30	18	120	2,77
1-6-19-1	4,20	0,159	72,3	33	21	112	3,81
1-6-20-1	4,40	0,108	145,4	25	14	100	2,26
1-6-21-1	4,35	0,110	83,6	31	15	96	2,53
1-6-22-1	4,35	0,111	98,2	21	17	133	2,77
1-6-23-1	4,40	0,128	87,2	23	18	155	3,31
1-6-24-1	4,15	0,109	85,8	26	17	108	2,56
1-6-25-1	4,40	0,095	70,8	23	12	84	2,29
1-6-26-1	4,30	0,104	106,5	30	18	150	2,40
1-6-27-1	4,45	0,076	123,4	22	12	96	1,75
1-6-28-1	4,45	0,093	119,4	32	16	104	2,18
1-6-29-1	4,35	0,098	105,7	25	13	96	2,40
1-6-30-1	4,40	0,077	131,3	26	16	104	1,79
1-6-31-1	4,50	0,074	121,9	23	10	80	1,50
1-6-32-1	4,60	0,061	160,4	16	9	80	1,05

Table 9.7: Soil composition for each individual sub-plot of St.Louis
du Ha! Ha! Station, plot #2.1.

Sample	pH	$\frac{N}{\%}$	$\frac{P}{ppm}$	$\frac{K}{ppm}$	$\frac{Mg}{ppm}$	$\frac{Ca}{ppm}$	$\frac{Org.C}{\%}$
2-1- 1-1	4,50	0,219	104,5	155	80	531	4,51
2-1- 2-1	4,50	0,196	75,9	108	41	774	3,75
2-1- 3-1	4,50	0,167	64,2	104	36	481	2,97
2-1- 4-1	4,50	0,207	48,2	106	53	960	4,15
2-1- 5-1	4,45	0,211	54,8	71	60	944	3,89
2-1- 6-1	4,45	0,192	64,3	71	52	891	3,55
2-1- 7-1	4,55	0,200	73,5	85	70	937	3,50
2-1- 8-1	4,60	0,204	71,8	105	61	795	3,55
2-1- 9-1	4,60	0,206	98,7	130	110	832	3,81
2-1-10-1	4,60	0,162	104,0	124	107	767	3,41
2-1-11-1	4,60	0,201	103,5	118	124	724	3,73
2-1-12-1	4,55	0,188	120,2	117	114	795	3,71
2-1-13-1	4,65	0,180	103,6	116	128	774	3,20
2-1-14-1	4,70	0,173	100,1	101	136	914	3,29
2-1-15-1	4,65	0,179	108,5	110	95	767	3,05
2-1-16-1	4,55	0,162	93,5	105	113	525	2,89
2-1-17-1	4,80	0,197	87,5	125	134	1267	3,98
2-1-18-1	4,75	0,228	94,3	136	120	1485	4,48
2-1-19-1	4,80	0,198	95,2	135	129	1276	3,84
2-1-20-1	4,75	0,188	82,8	128	124	1102	3,42
2-1-21-1	4,70	0,188	84,0	97	133	999	3,68
2-1-22-1	4,70	0,180	78,9	122	98	937	3,60
2-1-23-1	4,65	0,216	98,5	115	117	1086	4,33
2-1-24-1	4,60	0,206	111,2	131	93	991	3,96
2-1-25-1	4,75	0,187	88,2	125	74	876	3,29
2-1-26-1	4,75	0,148	79,3	135	66	760	3,02
2-1-27-1	4,60	0,182	87,8	129	114	869	3,27
2-1-28-1	4,80	0,185	72,0	99	139	1184	3,44
2-1-29-1	4,80	0,138	117,9	126	115	810	2,64
2-1-30-1	4,80	0,178	105,6	116	117	1078	3,62
2-1-31-1	4,80	0,182	132,1	148	107	1014	3,41
2-1-32-1	4,70	0,178	109,2	108	141	817	3,12

Table 9.8: Soil chemical composition for each individual sub-plot of
St-Louis du Ha! Ha! Station, plot #2.2.

Sample	pH	$\frac{N}{\%}$	$\frac{P}{ppm}$	$\frac{K}{ppm}$	$\frac{Mg}{ppm}$	$\frac{Ca}{ppm}$	$\frac{Org.C}{\%}$
2-2- 1-1	4,65	0,223	67,4	92	124	1134	4,20
2-2- 2-1	4,65	0,207	85,2	119	119	991	4,15
2-2- 3-1	4,75	0,194	62,0	116	146	861	3,53
2-2- 4-1	4,75	0,178	90,4	137	184	724	3,62
2-2- 5-1	4,85	0,180	94,0	145	188	983	3,81
2-2- 6-1	4,60	0,159	94,8	112	134	494	3,06
2-2- 7-1	4,85	0,210	133,9	127	160	1014	4,56
2-2- 8-1	4,95	0,190	137,7	117	155	1070	4,26
2-2- 9-1	4,80	0,160	97,2	101	159	944	2,93
2-2-10-1	4,75	0,155	149,3	128	154	825	3,15
2-2-11-1	4,60	0,163	149,3	100	112	767	3,20
2-2-12-1	4,75	0,142	105,1	104	173	582	2,85
2-2-13-1	4,75	0,152	108,4	134	154	609	2,88
2-2-14-1	4,75	0,196	105,4	119	146	975	3,87
2-2-15-1	4,70	0,129	120,8	117	109	410	2,90
2-2-16-1	4,75	0,193	137,4	105	95	869	4,76
2-2-17-1	4,90	0,225	124,3	108	162	1126	5,46
2-2-18-1	4,95	0,226	141,7	106	156	1362	5,02
2-2-19-1	4,90	0,279	138,9	97	192	1722	6,80
2-2-20-1	4,55	0,169	93,6	94	95	488	4,45
2-2-21-1	4,55	0,155	107,1	91	105	416	4,17
2-2-22-1	4,60	0,175	127,9	115	119	519	4,40
2-2-23-1	4,55	0,140	104,8	103	98	289	3,71
2-2-24-1	4,50	0,164	81,9	121	104	332	4,15
2-2-25-1	4,80	0,212	143,3	90	140	1110	5,06
2-2-26-1	4,75	0,213	103,5	107	128	1014	4,56
2-2-27-1	4,85	0,272	113,9	103	128	1458	6,04
2-2-28-1	4,60	0,198	100,5	103	113	609	4,89
2-2-29-1	4,50	0,211	101,1	93	161	563	5,86
2-2-30-1	4,55	0,193	111,5	86	140	512	4,83
2-2-31-1	4,50	0,171	100,4	90	106	416	4,59
2-2-32-1	4,45	0,204	123,1	98	84	525	5,38

Table 9.9: Soil chemical composition for each individual sub-plot of
St.Louis du Ha! Ha! Station, plot #2.3.

Sample	pH	$\frac{N}{\%}$	$\frac{P}{ppm}$	$\frac{K}{ppm}$	$\frac{Mg}{ppm}$	$\frac{Ca}{ppm}$	$\frac{Org.C}{\%}$
2-3- 1-1	4,45	0,182	85,1	89	99	387	4,32
2-3- 2-1	4,45	0,196	63,2	77	143	416	5,55
2-3- 3-1	4,45	0,181	71,9	81	88	428	4,88
2-3- 4-1	4,50	0,185	73,3	76	93	582	4,48
2-3- 5-1	4,55	0,209	91,4	98	121	922	4,78
2-3- 6-1	4,65	0,230	90,2	74	155	1362	5,42
2-3- 7-1	5,00	0,248	101,6	63	192	2720	6,03
2-3- 8-1	5,05	0,204	97,3	53	174	2256	4,86
2-3- 9-1	4,30	0,175	123,4	88	95	433	4,39
2-3-10-1	4,45	0,175	83,6	81	97	428	4,83
2-3-11-1	4,45	0,182	85,7	83	91	506	4,53
2-3-12-1	4,50	0,17	90,0	78	87	488	3,31
2-3-13-1	4,65	0,20	136,9	84	213	731	5,15
2-3-14-1	4,55	0,22	79,5	64	144	1657	5,54
2-3-15-1	4,65	0,19	72,1	131	131	475	4,07
2-3-16-1	4,65	0,20	90,0	105	134	869	4,91
2-3-17-1	5,10	0,22	72,3	53	164	2429	5,73
2-3-18-1	4,95	0,20	71,9	63	156	1638	4,65
2-3-19-1	4,85	0,21	84,5	103	160	1094	4,84
2-3-20-1	4,65	0,19	91,8	73	64	717	3,93
2-3-21-1	4,60	0,15	50,5	85	75	469	2,96
2-3-22-1	4,50	0,22	46,8	87	104	662	5,35
2-3-23-1	4,75	0,25	40,7	73	140	1293	6,45
2-3-24-1	4,95	0,26	60,3	61	178	2057	6,46
2-3-25-1	4,55	0,24	70,3	86	136	1388	6,58
2-3-26-1	4,55	0,21	79,6	94	95	983	5,28
2-3-27-1	4,60	0,22	75,3	92	107	922	4,76
2-3-28-1	4,80	0,20	78,0	106	105	991	4,87
2-3-29-1	4,85	0,18	73,6	105	93	1070	4,58
2-3-30-1	4,80	0,20	61,4	97	105	1242	5,02
2-3-31-1	4,90	0,20	60,0	82	108	1344	5,63
2-3-32-1	4,80	0,21	64,2	102	119	1310	5,90

Table 9.10: Soil chemical composition for each individual sub-plot of Amos Station, plot #3.1.

Sample	pH	$\frac{N}{\%}$	$\frac{P}{ppm}$	$\frac{K}{ppm}$	$\frac{Mg}{ppm}$	$\frac{Ca}{ppm}$	$\frac{Org.C}{\%}$
3-1- 1-1	4,70	0,094	25,1	31	30	279	2,17
3-1- 2-1	5,15	0,074	66,3	33	18	342	1,29
3-1- 3-1	5,80	0,071	120,1	30	16	531	1,14
3-1- 4-1	6,25	0,044	105,9	25	19	847	0,92
3-1- 5-1	5,80	0,044	83,3	28	16	451	0,88
3-1- 6-1	5,90	0,047	77,8	28	14	556	0,84
3-1- 7-1	5,05	0,038	21,3	25	19	205	0,79
3-1- 8-1	5,50	0,067	38,4	43	17	263	0,76
3-1- 9-1	5,10	0,042	23,4	39	16	219	0,76
3-1-10-1	5,05	0,067	52,4	41	20	238	1,02
3-1-11-1	5,15	0,095	70,3	42	27	268	1,25
3-1-12-1	5,05	0,080	69,8	31	13	214	1,45
3-1-13-1	4,75	0,063	61,5	29	11	260	1,39
3-1-14-1	5,50	0,056	104,3	35	28	748	1,21
3-1-15-1	6,40	0,042	158,1	25	18	1366	0,91
3-1-16-1	6,05	0,050	72,0	32	21	894	0,84
3-1-17-1	4,55	0,037	36,6	24	10	210	0,68
3-1-18-1	5,15	0,039	34,7	31	16	421	0,75
3-1-19-1	5,50	0,072	34,6	30	17	767	1,18
3-1-20-1	5,65	0,034	52,7	24	14	401	0,59
3-1-21-1	5,75	0,042	58,5	31	22	629	0,72
3-1-22-1	5,80	0,065	73,1	28	12	698	0,88
3-1-23-1	5,05	0,076	76,0	34	14	461	1,24
3-1-24-1	5,10	0,075	48,2	41	16	461	1,12
3-1-25-1	5,30	0,036	15,5	25	14	511	0,69
3-1-26-1	5,20	0,037	19,3	24	15	491	0,59
3-1-27-1	5,25	0,044	33,0	25	12	530	0,87
3-1-28-1	4,65	0,118	22,5	30	27	451	2,26
3-1-29-1	5,20	0,057	32,0	26	13	461	1,08
3-1-30-1	4,90	0,066	28,5	27	18	451	1,35
3-1-31-1	4,75	0,028	35,8	27	12	230	0,55
3-1-32-1	4,75	0,063	19,4	33	17	301	1,31

Table 9.11: Soil chemical composition for each individual sub-plot of Amos Station, plot #3.2.

Sample	pH	N %	P ppm	K ppm	Mg ppm	Ca ppm	Org.C %
3-2- 1-1	5,30	0,049	76,5	46	28	520	1,03
3-2- 2-1	5,45	0,042	59,7	50	31	491	0,89
3-2- 3-1	5,45	0,052	68,9	59	32	511	1,07
3-2- 4-1	5,00	0,061	36,0	53	32	461	1,35
3-2- 5-1	5,00	0,056	23,3	32	33	530	1,31
3-2- 6-1	4,80	0,089	21,3	33	36	620	2,23
3-2- 7-1	4,80	0,086	27,0	36	35	530	2,14
3-2- 8-1	4,90	0,074	23,1	31	32	501	1,68
3-2- 9-1	5,75	0,044	70,1	69	15	865	0,92
3-2-10-1	5,00	0,041	28,4	29	17	311	0,99
3-2-11-1	5,15	0,062	29,0	41	29	481	1,09
3-2-12-1	5,05	0,072	17,6	38	33	560	1,52
3-2-13-1	5,00	0,077	21,0	40	33	570	1,75
3-2-14-1	4,85	0,093	28,6	40	42	600	2,22
3-2-15-1	4,85	0,155	27,2	45	91	816	4,10
3-2-16-1	4,55	0,137	19,4	55	66	530	3,17
3-2-17-1	5,50	0,097	35,8	48	29	1030	1,69
3-2-18-1	5,15	0,068	19,4	26	22	796	1,48
3-2-19-1	4,75	0,082	15,4	20	27	659	1,91
3-2-20-1	4,75	0,102	27,2	23	41	639	1,98
3-2-21-1	5,20	0,076	58,1	33	59	816	1,67
3-2-22-1	4,95	0,068	109,6	42	112	787	1,58
3-2-23-1	4,40	0,124	36,9	31	60	411	2,79
3-2-24-1	4,35	0,113	70,6	34	72	451	2,84
3-2-25-1	5,05	0,056	46,4	33	25	371	0,78
3-2-26-1	4,85	0,115	49,6	102	134	1499	2,37
3-2-27-1	4,75	0,103	51,2	36	62	570	2,21
3-2-28-1	4,90	0,094	117,6	46	68	698	2,18
3-2-29-1	5,10	0,033	170,5	28	63	550	0,93
3-2-30-1	4,60	0,088	93,8	32	68	501	2,05
3-2-31-1	4,25	0,139	44,9	30	43	401	3,44
3-2-32-1	4,80	0,063	131,1	38	100	708	1,40

Table 9.12: Soil chemical composition for each individual sub-plot
of Amos Station, plot #3.3.

Sample	pH	<u>N</u> %	<u>P</u> ppm	<u>K</u> ppm	<u>Mg</u> ppm	<u>Ca</u> ppm	<u>Org.C</u> %
3-3- 1-1	4,60	0,118	31,1	31	71	649	2,66
3-3- 2-1	4,60	0,108	41,0	27	56	560	2,58
3-3- 3-1	4,60	0,123	40,8	45	68	550	2,69
3-3- 4-1	4,75	0,096	27,4	29	41	501	1,90
3-3- 5-1	4,65	0,136	23,1	29	78	520	2,77
3-3- 6-1	4,95	0,139	19,0	45	118	816	3,45
3-3- 7-1	4,80	0,130	21,0	48	89	738	3,38
3-3- 8-1	4,85	0,143	35,2	54	88	836	3,71
3-3- 9-1	4,50	0,115	21,5	48	66	580	2,58
3-3-10-1	4,40	0,102	29,0	42	55	421	2,18
3-3-11-1	4,80	0,090	27,3	40	62	590	1,86
3-3-12-1	4,80	0,140	19,1	34	135	649	2,99
3-3-13-1	4,60	0,170	28,5	46	85	718	4,14
3-3-14-1	4,85	0,119	54,2	38	85	698	2,86
3-3-15-1	4,85	0,087	80,2	34	112	698	1,96
3-3-16-1	4,90	0,124	94,0	61	169	1165	3,58
3-3-17-1	4,85	0,107	23,1	45	71	698	3,60
3-3-18-1	4,65	0,092	45,5	28	26	391	2,32
3-3-19-1	4,95	0,152	17,4	36	121	836	3,93
3-3-20-1	4,85	0,135	53,9	44	135	757	3,54
3-3-21-1	5,00	0,144	34,2	53	140	982	4,03
3-3-22-1	5,00	0,105	40,6	58	86	796	2,69
3-3-23-1	5,00	0,085	117,6	46	187	1088	2,58
3-3-24-1	5,10	0,126	99,8	42	203	1546	3,38
3-3-25-1	4,60	0,079	83,1	35	108	629	2,20
3-3-26-1	4,75	0,135	49,1	38	145	845	3,37
3-3-27-1	4,40	0,097	71,1	30	81	471	2,79
3-3-28-1	4,60	0,096	86,2	43	92	610	2,67
3-3-29-1	4,95	0,138	46,7	49	123	982	2,58
3-3-30-1	4,90	0,145	72,4	44	156	1107	4,02
3-3-31-1	5,00	0,120	67,0	32	183	1184	3,48
3-3-32-1	5,90	0,032	246,6	50	208	1184	1,03

Table 9.13: Soil chemical composition for each individual sub-plot of Amos Station, plot #3.4.

Sample	pH	$\frac{N}{\%}$	$\frac{P}{ppm}$	$\frac{K}{ppm}$	$\frac{Mg}{ppm}$	$\frac{Ca}{ppm}$	$\frac{Org.C}{\%}$
3-4- 1-1	5,00	0,082	109,6	41	133	767	2,05
3-4- 2-1	5,05	0,114	64,1	79	126	923	2,65
3-4- 3-1	4,75	0,156	38,6	83	112	845	3,30
3-4- 4-1	4,65	0,163	29,2	92	104	767	3,38
3-4- 5-1	5,00	0,077	86,7	63	118	787	1,49
3-4- 6-1	4,85	0,096	104,2	55	182	933	1,90
3-4- 7-1	4,80	0,131	64,4	75	160	1069	2,88
3-4- 8-1	4,85	0,122	70,4	63	166	1126	2,75
3-4- 9-1	5,00	0,153	108,6	71	210	1565	3,40
3-4-10-1	5,30	0,107	147,1	51	242	1565	3,05
3-4-11-1	5,00	0,104	114,4	62	181	1280	2,77
3-4-12-1	5,80	0,039	234,0	73	246	1366	0,86
3-4-13-1	5,40	0,059	152,3	47	194	1174	1,29
3-4-14-1	5,00	0,095	77,5	51	211	1356	2,93
3-4-15-1	5,20	0,079	118,9	46	211	1261	1,73
3-4-16-1	5,80	0,037	230,3	60	215	1232	0,64
3-4-17-1	5,40	0,133	106,2	63	246	1912	3,31
3-4-18-1	5,40	0,110	146,5	65	249	1555	2,99
3-4-19-1	5,20	0,139	112,9	68	241	1423	3,79
3-4-20-1	5,45	0,083	101,6	53	202	1385	1,81
3-4-21-1	5,50	0,090	146,0	43	227	1518	1,75
3-4-22-1	5,45	0,093	140,0	39	212	1499	1,91
3-4-23-1	6,00	0,055	179,8	59	225	1356	1,22
3-4-24-1	5,75	0,054	149,3	42	219	1356	1,13
3-4-25-1	5,55	0,053	197,2	56	195	1366	1,37
3-4-26-1	5,30	0,132	121,4	45	243	1772	3,49
3-4-27-1	5,45	0,081	169,7	42	225	1432	2,22
3-4-28-1	5,60	0,055	193,7	46	233	1270	1,46
3-4-29-1	5,65	0,077	145,9	43	240	1451	1,53
3-4-30-1	5,45	0,064	150,8	37	202	1375	1,44
3-4-31-1	5,70	0,083	141,5	51	228	1480	1,89
3-4-32-1	5,65	0,119	83,5	44	267	1912	2,83

Table 10 Methods of leaf analysis

Parameters	Methods	References
Drying	Oven with forced air circulation (65°C, 48 hours)	
Grinding	Arthur Thomas Mill (20 mesh)	
Total nitrogen	Micro Kjeldahl	Cole and Parks, 1946 (1)
Treatment of samples	Nitric and perchloric acids	Johnson and Ulrich, 1959 (2)
- Total phosphorus	Phosphovanadomolybdic acid	Kitson and Mellon, 1944 (3)
- Potassium	Atomic absorption	
- Magnesium		
- Calcium		

- (1) Cole, J.O. and Parks, C.P. 1946. Anal. Chem. 18: 61.
- (2) Johnson, C.M. and Ulrich, A. 1959. California Agr. Exp. Sta. Bull. 766.
- (3) Kitson, R.E. and Mellon, M.G. 1944. Ind. Eng. Chem. 16: 379-389.

The nitrogen content of the poplar leaves ranged from .98% to 3.27%, compared with 2.03% to 3.42% for the willows and 2.65% to 3.81% for alder. The potassium levels in the willow leaves were up to 22,130 ppm, which was considerably higher than any alder sampled. (Tables 11,12 and 13).

2.4 Work in the 1982 to 1983 period

It is suggested that during the 1982-1983 period the following work is carried out:

Spring 1982 - Select the plots for continued intensive study

- Complete chemical analyses of samples collected in the fall of 1981.

- Analyse the physical characteristics of the soils on all plots, particularly at Amos.

Late Summer, - Complete the tree measurements.
Fall 1982

3. FRANKIA STRAIN SELECTION - (DR. M. LALONDE AND MR. PHILIPPE NORMAND)

The work on Frankia strain selection started in 1980 to 1981, and was carried out by Mr. Philippe Normand under the direction of Dr. Maurice Lalonde.

A full description of the work is being prepared as an M.Sc. thesis. (Normand, Philippe, 1982. Isolement, caractérisation et évaluation de diverses souches de Frankia), and will be available for publication by ENFOR later.

Frankia strains were collected from 27 provenances of Alnus crispa and A. rugosa, both of which are native to Quebec (Table 14). Latitudes of locations ranged from 46°35' North to 55°40' North and longitudes 64°10' West to 73°50' West. The alders grew on soils which include clay

Table 11 Leaf characteristics of hybrid poplar.

35.

Sample	Leaf Wt. (g)	N (%)	P K Mg Ca			
			(ppm)			
1-1-06-1	0.61	2.03	1150	7380	3329	4992
1-1-17-1	0.78	1.93	1044	5943	3729	3559
1-1-20-1	1.13	1.83	1233	5011	3102	3422
1-1-21-1	0.94	2.06	1003	5908	3335	3973
1-1-25-1	0.77	1.80	1337	6064	2982	6050
1-1-31-1	1.00	2.03	1119	6116	3909	5820
1-2-04-1	0.54	2.07	1384	5720	3102	5365
1-2-06-1	0.65	2.33	1348	7619	2320	5744
1-2-08-1	1.02	2.41	1621	7343	3281	5066
1-2-10-1	0.49	1.21	892	4547	3251	6988
1-2-21-1	0.57	2.17	1170	7017	2614	5440
1-2-27-1	1.19	1.98	1457	6272	3263	5668
1-5-01-1	0.86	1.60	1160	9506	1483	1807
1-5-02-1	0.73	1.75	1094	9891	1412	1509
1-5-05-1	0.91	1.67	1532	9850	2218	2752
1-5-22-1	1.12	1.49	1134	6963	1858	2687
1-5-23-1	0.50	1.54	1034	7545	1423	2114
1-6-03-1	0.62	1.37	1039	7417	1996	3491
1-6-04-1	1.04	1.61	1264	11459	2230	3218
1-6-11-1	1.09	1.49	1212	9029	1904	2687
1-6-16-1	0.63	1.53	1151	7380	1841	3218
1-6-22-1	0.46	1.16	995	5634	2116	4263
1-6-32-1	0.66	1.53	1074	8351	1549	2239
2-1-05-1	0.76	1.58	1827	9586	2131	3491
2-1-09-1	0.94	1.32	191	12701	2560	4771
2-1-12-1	0.98	3.27	2253	12196	1953	2752
2-1-14-1	0.73	1.33	2011	11437	1989	3354
2-1-26-1	0.57	0.98	1320	9688	2381	4479
2-1-31-1	0.86	1.15	1452	11547	2068	3978
2-2-02-1	0.85	2.51	1566	10661	2054	3629
2-2-04-1	0.32	1.26	1853	12287	2072	3354
2-2-06-1	0.70	1.19	1303	12173	2184	3151
2-2-13-1	0.46	1.03	1451	9789	2857	4697
2-2-14-1	0.77	1.35	1296	10138	2214	3908
2-2-31-1	0.55	1.59	1980	9446	2447	3354
2-3-05-1	0.73	1.58	1867	10304	2316	3978
2-3-11-1	0.59	1.38	1269	12864	2116	3978
2-3-13-1	0.54	1.49	1860	8852	2898	5066
2-3-20-1	0.49	1.70	2033	10619	2418	5592
2-3-21-1	0.40	1.76	-	-	-	-
2-3-30-1	0.47	1.18	1652	5312	2711	6988
3-1-01-1	-	1.87	1061	7089	2057	4918
3-1-06-1	-	2.07	1907	7693	1786	5592
3-1-08-1	-	1.20	808	7435	1731	5440
3-1-09-1	-	1.89	1275	6927	2161	6205
3-1-11-1	-	2.03	1337	5295	2356	6673
3-1-32-1	-	1.67	1187	9891	1693	2176
3-2-02-1	-	2.05	1602	8180	2618	7949
3-2-03-1	-	1.68	1754	8600	2618	6909
3-2-15-1	-	1.44	1091	6501	2929	7306
3-2-21-1	-	1.47	882	6891	2234	5516
3-2-27-1	-	2.16	1365	6220	2296	3559
3-2-29-1	-	1.85	867	5771	1690	3838
3-3-14-1	-	2.13	920	5960	2961	4263
3-3-19-1	-	2.42	1139	5077	4148	5592
3-3-22-1	-	1.58	952	7435	2304	5365
3-3-26-1	-	2.18	-	-	-	-
3-3-29-1	-	1.42	1029	6695	2888	4844
3-3-31-1	-	1.96	1034	4269	2687	3286
3-4-04-1	-	1.83	1034	8218	2127	2950
3-4-18-1	-	1.48	803	6012	2065	4771
3-3-20-1	-	1.69	1014	4580	2028	4552
3-4-26-1	-	1.79	1231	4156	2360	3218
3-4-29-1	-	1.63	1160	3099	3435	6516
3-4-31-1	-	1.83	1081	4384	2494	5140

Table 12 Leaf characteristics of Salix alba.

Sample	Leaf weight (g)	N (%)	P	K (ppm)	Mg	Ca
1-1-02-1	0.07	2.99	1458	10450	3019	5516
1-1-04-1	0.05	2.81	1757	7289	3880	3083
1-1-10-1	0.07	2.51	1365	7991	3124	7226
1-1-29-1	0.05	2.98	1470	12355	2304	5973
1-1-32-1	0.06	2.92	1362	8892	3821	6438
1-2-02-1	0.07	3.09	2147	6413	4209	7306
1-2-09-1	0.07	2.93	2287	7234	4340	8111
1-2-11-1	0.07	2.99	1485	6307	3914	8030
1-2-19-1	0.07	3.24	1517	8370	2348	8693
1-2-20-1	0.05	3.42	1325	12219	2127	8693
1-2-26-1	0.06	3.25	1615	6600	4280	6516
1-5-06-1	0.07	2.73	1160	11903	1717	3559
1-5-13-1	0.05	2.78	1359	14461	1796	3838
1-5-17-1	0.07	2.70	1384	12585	2157	5744
1-5-28-1	0.05	2.42	1264	9088	1569	5215
1-5-30-1	0.06	2.62	1222	9748	1928	4191
1-5-32-1	0.05	2.42	1180	10492	1855	4918
1-6-07-1	0.06	2.09	1030	9526	1992	6128
1-6-19-1	0.05	2.40	1275	9426	2507	6438
1-6-21-1	0.05	2.39	1275	11591	1978	4335
2-1-03-1	0.05	2.56	1867	18495	2555	8519
2-1-08-1	0.05	2.75	1887	19940	2389	6050
2-1-11-1	0.05	2.66	1722	20180	2452	6360
2-1-20-1	0.05	2.50	1807	17620	2203	6360
2-1-27-1	0.05	2.43	1659	22130	2632	3978
2-1-32-1	0.06	2.62	1690	17700	2555	6360
2-2-09-1	0.05	2.28	1535	15668	2664	6673
2-2-11-1	0.05	2.36	2208	20825	2573	4697
2-2-15-1	0.05	2.03	1382	20420	3158	5140
2-2-16-1	0.05	2.19	1535	20020	2456	5516
2-2-17-1	0.06	2.35	1928	17540	2529	8683
2-2-18-1	0.06	2.51	1827	14511	2499	8683
2-3-01-1	0.05	2.51	1590	15147	3880	7386
2-3-06-1	0.05	2.43	2200	15302	2499	7386
2-3-14-1	0.04	2.10	1348	13990	3233	11182
2-3-23-1	0.05	2.54	1840	15410	2494	5290
2-3-32-1	0.04	2.52	2076	16039	2180	8356

Table 13 Leaf characteristics of Alnus glutinosa.

Sample	Leaf weight (g)	N (%)	(ppm)				
			P	K	Mg	Ca	
1-1-01-1	0.41	3.46	1602	4663	3158	2950	
1-1-15-1	0.47	3.06	1308	4204	4916	6438	
1-1-22-1	0.48	3.45	1382	5061	2725	5290	
1-1-23-1	0.38	3.16	1382	4188	2940	6050	
1-2-18-1	0.45	3.62	1376	5685	3008	7386	
1-2-23-1	0.57	3.37	1400	4302	2054	3978	
1-2-24-1	0.54	3.81	1491	6046	2623	5973	
1-2-28-1	0.46	3.31	1462	4465	2582	8437	
1-5-11-1	0.33	3.15	1514	3929	1279	5516	
1-5-14-1	0.33	2.65	1780	4482	1323	3838	
1-5-15-1	0.54	2.87	1986	5295	1731	3218	
1-5-26-1	0.31	3.37	1615	5061	1648	7707	
1-6-10-1	0.33	2.84	1440	3752	2385	7707	
1-6-18-1	0.46	3.15	1485	5447	1676	5365	

Table 14 - Location of Frankia provenances

Location	Soil type	Origin	Longitude	Latitude
Tadoussac	Sandy	AC ^{1/}	48°10'	69°40'
Cap-aux-Oies	Sandy Loam	AC	47°30'	70°15'
Lac Beauport	Sandy	AC	47°00'	71°15'
Gaspé	Sandy	AC	48°55'	64°35'
Percé	Sandy Loam	AC	48°30'	64°10'
Baie St-Paul	Sandy	AC	47°25'	70°30'
Tadoussac	Sandy	AC	48°10'	69°40'
Baie St-Paul	Sandy	AC	47°25'	70°30'
Petite Rivière	Sandy	AC	47°20'	70°35'
Petite Rivière	Sandy	AC	47°20'	70°35'
Tadoussac	Sandy	AC	48°10'	69°40'
Ste-Monique	Sandy	T ^{2/}	48°45'	71°50'
Breakville	Clay Loam	AC	46°40'	71°50'
Manitouneuk	Sandy	T	55°40'	77°25'
St-Louis-des Aulnaies	Sandy	AC	47°15'	70°05'
Port-au-Persil	Sandy	AC	47°50'	69°50'
Pointe-à-la-Garde	Sandy	ARg ^{3/}	48°05'	67°25'
Quebec City	Sandy Loam	ARg	46°45'	71°25'
Tadoussac	Clay Loam	ARg	48°10'	69°40'
Sherbrooke	Clay Loam	ARg	45°25'	71°55'
St-Calixte	Clay Loam	ARg	45°55'	73°50'
St-Samuel	Sandy	ARg	46°05'	72°15'
St-Pierre	Clay Loam	ARg	46°15'	71°35'
Grand-Mère	Sandy	ARg	46°35'	72°40'
St-Magloire	Sandy	ARg	46°35'	70°15'
St-Omer	Sandy	ARg	47°05'	69°40'
Albanel	Clay Loam	ARg	48°50'	72°20'

Note. A map showing distribution of these sites was provided in the 1980-81 report for ENFOR p-78

1/ AC = Alnus crispa

2/ T = Growth-pouch-seedlings infected by soil containing Frankia

3/ ARg = Alnus rugosa

loams, sandy loams and sand. More than 200 Frankia strains were obtained and established in a culture collection at Laval University. This collection represents over 75% of all the Frankia isolates in the World, and constitutes an invaluable source of Frankia genes for future work.

All of the Frankia isolates have been assessed for morphology, infectivity and effectivity. There were definite variations in these factors between provenances, and even within provenances. Full details of techniques were described in the 1980-1981 ENFOR p-78 Report.

Pure cultures of Frankia are necessary for these assessments. In the past crushed nodules have been used to provide inocula, but unfortunately compounds present in the crushed nodules affect the results. Before 1978 no pure cultures were available, and about 40 teams of researchers have been trying to solve the associated problems.

A time-consuming enzymatic method was evolved by Callahan in 1978. More recently (1981) the Osmium tetroxide treatment was developed by Dr. Lalonde, who joined the ENFOR project last year. This method is reliable and easy to use. It can yield many Frankia isolates from one alder nodule lobe. Osmium is toxic and needs care in handling, but there are few problems an efficient fume cupboard is used.

A 30 pages paper entitled "Evaluation of Frankia strains isolated from provenances of two Alnus species", by P. Normand, J.A. Fortin and M. Lalonde is attached to this report as an Appendix under separate cover for information. It has been submitted to the Canadian Journal of Microbiology.

In addition a note entitled "Comparison of six surface sterilizing agents for aseptic germination of Alnus crispa (Fern.) Push." by P. Normand and J.A. Fortin has been submitted for publication. A paper was also given

at the 49th ACFAS Congress at Sherbrooke on the isolation of a strain of Frankia from alder.

This work is now complete except for the final M.Sc. thesis. It has been very productive and has broken new ground. Mr. Philippe Normand has decided to carry on research on Frankia genetics, at the Ph.D. level with Dr. Maurice Lalonde.

4. FRANKIA INOCULUM PRODUCTION AND APPLICATION (DR. M. LALONDE AND MR. PHILIPPE NORMAND)

The completion of the work on selection of Frankia strains and formation of a gene bank is described in paragraph 3. As a corollary to this work a method of producing the Frankia strains and applying them has been developed, tested and completed.

The methods were applied to 1.2 million alder (Alnus crispa) seedlings in March 1981. The inoculation was completely successful, and fully nodulated seedlings were planted during the summer of 1981 for land reclamation in the James Bay area. The large scale production and inoculation was funded by the Société d'Énergie de la Baie James (Hydro-Québec). It provided a first class operational test of the Frankia production and inoculation technique.

Already a private company "Les Laboratoires Rhizotec, Inc." located at St-Jean-Chrysostôme, near Quebec City, is producing Frankia inoculum on a commercial basis, and there are export possibilities. The basic research has moved to the operational phase. The technology is ready for use.

The details of the techniques are fully described in the 1980 - 1981 ENFOR P-78 report.

5. SELECTION OF SUPERIOR MYCORRHIZAL SYMBIONTS ON WILLOWS, ALDERS AND POPLARS

This research program was initiated in 1980 - 1981. The preliminary

results were described in the 1980 - 1981 ENFOR P-78 progress report.

Very little work has been done on the ectomycorrhizae of alders, poplars and willows, all of which are promising for high yield, short rotation plantations.

In the 1980 - 1981 period of 46 pure cultures from 28 potentially mycorrhizal fungi from willow, alders, amelanchier, birch, white spruce, balsam poplar, trembling aspen, red pine and balsam fir were collected and successfully cultivated, using the techniques described in detail in the 1980 - 1981 ENFOR P-78 report. Definite mycorrhizae were produced by Paxillus involutus on trembling aspen and on Alnus crispa. Alnus crispa inoculated with the nitrogen-fixing actinomycete Frankia formed with typical mycorrhizae with Pisolithus tinctorius, Paxillus involutus, Alpora diphlo-
ploeus.

During 1981 - 1982 this work was extended and virtually completed for the alders and the poplars. Assays on willows have failed so far due to problems encountered in the collection and germination of the seeds.

86 strains of 67 different species of potentially ectomycorrhizal fungi were collected near host plants.

40 isolates grew sufficiently well on an agar medium to attempt experimental synthesis of ectomycorrhizae in growth pouches. Ectomycorrhizae formed with 8 isolates on Alnus crispa, 9 isolates on Alnus rugosa and 15 on Populus tremuloides. More successes are expected with the poplar in the near future (Table 15).

The mycorrhizae in both species of alders were atypical, with the usual external mantle but a shallow Hartig net. Only three species of fungi (Laccaria laccata), Paxillus involutus, and Cortinarius sp) readily

Table 15. Formation of ectomycorrhizae on Alnus rupestris, Alnus crispa var. mollis and Populus tremuloides by different species of fungus.

42.

SPECIES OF FUNGUS	Collection No.	<u>Alnus rupestris</u>	<u>Alnus crispa</u>	<u>Populus tremuloides</u>
<i>Alpeva diplophloeus</i>	125	+	+	
<i>Alpeva diplophloeus</i>	281	+	+	
<i>Amanita brunneescens</i>	245			
<i>Amanita citrina</i>	77-8	-		
<i>Amanita citrina</i>	259			
<i>Amanita flavoconia</i>	253			
<i>Amanita muscaria</i>	14			
<i>Amanita muscaria</i>	40	-		+
<i>Amanita muscaria</i>	59	-	-	+
<i>Amanita rubescens</i>	237	-		+
<i>Amanita virosa</i>	246			
<i>Amanita velleii</i>	3			
<i>Amanita velleii</i>	223			
<i>Boletus ornaticipes</i>	236			(-)
<i>Boletus piperatus</i>	16	(-)		(-)
<i>Boletus piperatus</i>	43			
<i>Cenococcum geophilum</i>	xx-50	-	+	+
<i>Cenococcum geophilum</i>	122	+	-	
<i>Cortinarius alboviolaceus</i>	274			
<i>Cortinarius hircynicus</i>	283			
<i>Cortinarius pseudonapae</i>	276			
<i>Cortinarius semisanguineus</i>	130			
<i>Cortinarius subporphyropus</i>	47	+	+	+
<i>Cortinarius sp.</i>	30	(-)		
<i>Cortinarius sp.</i>	231			
<i>Dyctyophora duplicata</i>	249			-
<i>Fuscoboletinus glandulosus</i>	77-9	-		
<i>Gautieria graveolens</i>	219	-		
<i>Gyrodon meruloides</i>	2	-	-	-
<i>Gyrodon meruloides</i>	225	-	-	-
<i>Gyromitra esculenta</i>	205	-	-	-
<i>Hebeloma crustuliniforme</i>	278			
<i>Hebeloma cylindrosporum</i>	75-1		-	
<i>Hebeloma mesophaeum</i>	208		-	+
<i>Hebeloma sp.</i>	273			
<i>Laccaria laccata</i>	4			
<i>Laccaria laccata</i>	211	+	+	+
<i>Lactarius hibbardae</i>	258			
<i>Lactarius pubescens</i>	277			
<i>Lactarius sp.</i>	66	-		(-)
<i>Lactarius sp.</i>	226			
<i>Leccinum aurantiacum</i>	53	-		+
<i>Leccinum eximium</i>	270			
<i>Leccinum griseonigrum</i>	22	-		+
<i>Leccinum holopus</i>	72	+	+	
<i>Leccinum insignis</i>	52			+
<i>Leccinum subglabripes</i>	235			
<i>Leccinum subglabripes</i>	242			
<i>Leccinum subleucophaeum</i>	269			
<i>Leccinum sp.</i>	33			
<i>Leccinum sp.</i>	91			
<i>Leccinum sp.</i>	243	(-)		
<i>Lycoperdon perlatum</i>	82		-	-
<i>Lycoperdon sp.</i>	68			
<i>Morchella conica</i>	202			-
<i>Marasmius caninus</i>	210	-		-
<i>Paxillus involutus</i>	9	+	+	+
<i>Paxillus involutus</i>	222			
<i>Pisolithus tinctorius</i>	76-1	+	+	+
<i>Psathyrella rigidipes</i>	77	(-)		
<i>Rhizopogon sp.</i>	218	-		-
<i>Rhizopogon sp.</i>	247	-		-
<i>Rhizopogon sp.</i>	261		-	-
<i>Rozites caperata</i>	227			
<i>Russula aeruginea</i>	214			
<i>Scleroderma arancicola</i>	240			
<i>Scleroderma citrinum</i>	65	+	+	+
<i>Scleroderma citrinum</i>	224			
<i>Scleroderma citrinum</i>	284			
<i>Scleroderma lycoperdoides</i>	241			
<i>Suillus grevillei</i>	77-12	-		
<i>Suillus tomentosus</i>	77-1	-		
<i>Thelophora terrestris</i>	128			+
<i>Tricholoma albobrunneum</i>	271			
<i>Tricholoma cingulatum</i>	260	-		
<i>Tricholoma flavobrunneum</i>	280			
<i>Tricholoma flavovirens</i>	41	-	-	(-)
<i>Tricholoma flavovirens</i>	256			
<i>Tricholoma populinum</i>	93	-		+
<i>Tricholoma sejunctum</i>	263			
<i>Xerocomus subtomentosus</i>	71	-	-	
<i>Xerocomus subtomentosus</i>	244			

+ : mycorrhizal

- : no mycorrhiza formed

(-) : no growth of the fungus in the growth pouch

formed mycorrhizae on all three of the host plants.

A Master's Thesis on this work is being prepared by Christian Godbout. In addition two papers are being prepared on the work done so far: Godbout, C. and J.A. Fortin 1982. Selection of mycorrhizal fungi on Alnus crispa. Can. J. Botany (in preparation); Godbout, C. and J.A. Fortin 1982. Optimal conditions for ectomycorrhizae formation on Populus tremuloides (provisional title), Can. J. Bot. (in preparation). A paper entitled "Les champignons ectomycorhiziens de l'Alnus crispa et du Populus tremuloides" was given at the ACFAS Congress in Montreal.

6. GROWTH AND SURVIVAL OF DIFFERENT PROVENANCES OF ALNUS GLUTINOSA
(MR. R. CAMIRAND)

The alders used in the field experiment described earlier were Alnus rugosa, A. crispa and A. glutinosa. The latter species is not native to Quebec and it is desirable that the performance in Quebec of the different genotypes within the species is understood.

In order to evaluate the growth and hardiness of Alnus glutinosa in the Quebec Region, seed from European sources was obtained, the seedlings raised, and the plants established on an experimental site on the Laval University Campus.

6.1 The seed

The seed for the first part of this study was provided by Dr. R.B. Hall of the University of Iowa. Seed of 43 provenances was obtained.

Most of the seed came from northern and central Europe, with the exception of one provenance (OX03) from the United States. The seeds were collected from both natural and artificial alder stands. The latter are represented by the following nine provenances: 4X56, OX03, 4X55, 2X03, 2X02, 4X31, 4X53, 4X14 and 4X18. The codes, location and elevation of the alder provenances are given in Table 16.

Table 16 Location of the Alnus glutinosa provenances used in the experiment;

44.

Provenance ^{1/}	Location	Latitude	Longitude	Elevation
2144	Molde, Norway	62°42'N	7°40'E	20
2612	Turku, Finland	60°25'N	22°15'E	5
2634	Helsinki, Finland	60°22'N	25°02'E	60
2652	Hameenlinna, Finland	60°55'N	24°25'E	100
2673	Ikaalinen, Finland	61°43'N	23°13'E	90
2812	Tartu Estonia, Russia	58°10'N	27°36'E	50
2813	Tartu Estonia, Russia	58°10'N	27°36'E	50
5420	Bialowieza, Poland	52°30' N	23°50'E	150
5813	Banska Stiavnika, Czechoslovakia	48°27'N	18°55'E	475
4X56 ^{2/}	Baden-Wurttemberg, W. Germany	-	-	-
6313	Basel, Switzerland	47°33'N	7°57'E	350
6365	Aarau, Switzerland	47°18'N	8°03'E	455
6513	Luneville, France	48°30'N	6°29'E	240
6523	Nancy, France	48°47'N	6°18'E	225
6531	Nancy, France	48°48'N	6°16'E	240
0X03	Luther, USA	41°56'N	93°52'W	290
7242	Durdevac, Yugoslavia	46°05'N	17°05'E	113
2163	Steinkjer, Norway	64°12'N	12°14'E	50
7213	Zagreb, Yugoslavia	45°49'N	16°01'E	120
7221	Novoselec, Yugoslavia	45°35'N	16°31'E	95
2811	Tartu Estonia, Russia	58°10'N	27°36'E	50
2125	Oslo, Norway	59°46'N	10°47'E	45
2220	Sakskobing, Denmark	54°45'N	11°30'E	-
1721	Wrexham, U.K.	52°57'N	3°02'W	50
4714	Offenburg, W. Germany	48°30'N	8°00'E	140
4723	Offenburg, W. Germany	48°30'N	8°00'E	140
7234	Durdevac, Yugoslavia	46°05'N	17°05'E	115
5621	Brzesko, Poland	49°50'N	20°10'E	220
1111	Killeshandra, Ireland	54° 'N	7°30'W	60
4713	Offenburg, W. Germany	48°30'N	8°00'E	140
2113	Oslo, Norway	59°40'N	10°47'E	80
6535	Nancy, France	48°48'N	6°16'E	240
4X55 ^{2/}	Baden-Wurttemberg, W. Germany	-	-	-
2X03	Kristianstad, Sweden	56°02'N	13°57'E	40
2X02 ^{3/}	Hassleholm, Sweden	56°07'N	13°50'E	30
4X31 ^{3/}	- - - - -	46°50'N	13°35'E	600
4X53	Munich, W. Germany	48° 'N	11° 'E	650
5411	Brzeziny, Poland	51°48'N	19°50'E	168
2912	Riga, Russia	56°44'N	24°09'E	30
4X14 ^{4/}	- - - - -	-	-	-
5413	Brzeziny, Poland	51°48'N	19°50'E	168
2914 ^{4/}	Riga, Russia	56°44'N	24°09'E	20
4X18 ^{4/}	- - - - -	-	-	-

- 1/ Seed lot code used by the Department of Forestry, University of Iowa, USA
 1st digit Geographic Region.
 2nd digit Geographic Sub-Region (X = artificial stand source)

- 2/ Plus tree selection in the seed orchards of Ochsenhausen (4X56) and
 Weilheim (4X55) in Western Germany, grafted and planted in an arboretum.

- 3/ Selected trees in parent tree (scion) orchard.

- 4/ Plus trees from West German seed orchards (Information from H. Weisgerber,
 Münden).

6.2 Characteristics of the experimental site

The site is located on the Laval University Campus at a latitude of about 46°46' North and a longitude of 71°16' West, at an elevation of 78 m.

The meteorological Station N. 7017BFN of the Ministry of the Environment, Quebec, is located at Ste-Foy - Pie XII, and records show that the mean temperature of the warmest month (July) is 20.5°C (15.1°C to 26.1°C), and in the coldest month (January) is -11.2°C (-15.8°C to 6.6°C). The mean total precipitation is 131.4 mm for July and 95.9 mm for January, including 49.8 cm of snow. The first frost occurs about the beginning of October, and the last frost about the beginning of May, giving a frost-free period of about 201 days.

6.3 Treatment of seeds and seedlings

About half of the seeds of each provenance was sown on July 7th, 1981. Seeds from each provenance were placed in a polyethylene covered tray containing 25 peat pots, each containing 5 seeds, a total of 125 seeds/tray. Before the experiment, the seeds were stored in a refrigerator at 4°C. The seeds did not receive any other initial treatment.

The soil medium consisted of a mixture of humus (Fafard), vermiculite, and sand (8 - 8 - 1) at a pH of 5.8.

Germination was assessed for the first time on 22nd July. On the same day the alder were inoculated with the nitrogen-fixing actinomycete Frankia ACNI^{AG} type and fertilised with Crône's solution (20mL/pot). The temperature of the greenhouse was maintained at 18° - 20°C and the pots were watered every two days.

6.4 Seed germination

Germination of the seeds was evaluated each week over a period of three weeks to give a measure of the germination capacity of the provenances (Table 17).

Without stratification, the seeds germinated in a period of two weeks, with the exception of certain provenances (4X55, 4X53, 2914) which germinated rapidly after the third week. In addition some of the provenances (2612, 1721, 4714, 4X31) did not germinate at all, and others (2634, 6365, 2163, 2811, 5411) had very poor germination.

Stratification of the seeds before sowing will probably reduce the germination time to less than one week. The percentage of germinated seeds doubled from the first to second week after sowing, with the exception of provenance 6313.

In these experimental conditions the provenances with the best germination are 2X03 (35%), 2912 (51%), 5413 (47%) and 4X18 (42%).

The reduction in cumulative germination in the third week in some provenances (5420, 6313 and 6513) was due to the etiolation and death of seedlings due to lack of light.

The seeds of these alder provenances were tested in germination cabinets by the University of Iowa in 1977 - 78. The results from Laval University's experiment show that the germination in the cabinets is generally better than in the soil mixture in the greenhouse, as is often the case. However, the germination of provenances 2125, 2X03, 2912, 4X14 and 1111 in the Laval experiment was not a great deal less than germination in the Iowa cabinets (Table 17).

Table 17 Germination of Alder Seed^{1/}

Provenance No.	Cumulative Germination (2)			Theoretical Germination ^{2/} (%)
	1st week	2nd week	3rd week	
2144	8	16	14	46
2612	0	0	0	43
2634	2	3	2	74
2652	1	8	8	36
2673	16	30	26	85
2812	6	14	10	64
2813	10	31	31	86
5420	12	27	16	64
5813	2	8	10	82
4X56	7	26	25	73
6313	29	32	13	45
6365	2	2	1	15
6513	6	25	16	80
6523	2	10	8	81
6531	1	8	11	52
0X03	0	4	6	15
7242	2	5	5	68
2163	3	4	2	31
7213	2	5	5	11
7221	6	8	6	27
2811	0	1	1	43
2125	8	18	18	20
2220	1	9	12	44
1721	0	0	0	56
4714	0	0	0	85
4723	0	14	18	77
7234	3	23	25	67
5621	0	5	6	66
1111	2	22	22	20
4713	5	20	22	86
2113	4	17	18	45
6535	0	5	9	62
4X55	0	10	24	56
2X03	10	42	35	58
2X02	6	26	29	60
4X31	0	0	0	-
4X53	1	12	20	69
5411	0	1	4	48
2912	14	50	51	77
4X14	14	22	22	29
5413	4	42	47	81
2914	2	14	23	86
4X18	1	37	42	71

1/ No seed selection or pretreatment

2/ Germination I in germination cabinets at University of Iowa.
Data provided by Dr. R.B. Hall.

6.5 Treatment after germination

After the seeds had germinated, the plants were fertilized on the 23rd July 1981. From the 31st July, they were illuminated for 15 hours/day. On the 10th August the watering was decreased, and the day length decreased prior to transferring the plants from the greenhouse to a shade hall. They were transplanted on 28th August 1981. On the 15th September the shade was removed and survival assessed. The heights of the plants were measured three days later, and the trees planted in the field experiment on 7th October 1981.

6.6 Survival of the shaded plants

The mortality of the plants of different provenances in the 3rd and 7th weeks under shade, and those available for planting are described in Table 18.

There was no significant difference between mortality in the 3rd week and that in the 7th week, so the losses occurred rapidly.

Some of the provenances, notably OX03, 7221, 2811, 2125, 2220, 4723, 2113, 4X55, 2X03, 2X02, 4X53 and 4X18, survived very well.

Although some provenances had heavy losses (eg. 2673, 2813, 2912) and seemed to have difficulty adapting to changes in their environment, it is not possible to reach any firm conclusions from this single experiment. A study will be initiated in the spring of 1982 to examine the physiological characteristics of these alders, to give a better idea of their hardiness.

6.7 Growth of the seedlings

The heights of the seedlings were measured eleven weeks after sowing (Table 19). Although the growth was only for part of the growing season, 7th July to the fall, differences in height growth of the different alder provenances were apparent. Of course these differences will probably change later.

Table 18 Alder Seedling Mortality

Provenance No.	No. of Plants		
	Cumulative Mortality		Planted
	3rd week	7th week	
2144	1.	15	2
2612	-	-	0
2634	3	3	0
2652	2	4	6
2673	17	19	14
2812	7	7	6
2813	20	20	19
5420	6	6	14
5813	5	5	8
4X56	13	13	18
6313	6	6	10
6365	1	1	0
6513	6	6	14
6523	6	6	4
6531	7	7	7
0X03	0	0	7
7242	2	2	4
2163	1	1	2
7213	2	2	4
7221	0	0	8
2811	0	0	1
2125	1	1	22
2220	0	0	15
1721	-	-	0
4714	-	-	0
4723	0	1	21
7234	4	4	27
5621	1	1	6
1111	6	6	21
4713	2	4	24
2113	1	1	21
6535	2	2	9
4X55	0	0	30
2X03	0	0	44
2X02	1	1	35
4X31	-	-	0
4X53	0	1	24
5411	0	1	4
2912	15	15	49
4X14	3	3	24
5413	5	5	54
2914	5	6	23
4X18	2	2	50

Table 19 Height of Alnus glutinosa after 11 weeks of growth

Provenance No.	Height (mm)		
	Minimum	Mean	Maximum
2144	-	25	-
2612	-	-	-
2634	-	-	-
2652	20	45	60
2673	25	35	55
2812	30	35	55
2813	20	40	70
5420	25	55	95
5813	25	45	90
4X56	20	40	70
6313	25	55	85
6365	-	-	-
6513	15	35	60
6523	35	50	70
6531	30	70	90
0X03	30	55	145
7242	35	50	70
2163	-	45	-
7213	30	45	85
7221	30	45	85
2811	-	45	-
2125	10	35	70
2220	20	45	80
1721	-	-	-
4714	-	15	-
4723	15	35	50
7234	15	40	70
5621	15	35	60
1111	25	50	75
4713	15	40	70
2113	15	30	50
6535	15	35	55
4X55	15	35	70
2X03	20	35	55
2X02	15	30	55
4X31	-	-	-
4X53	10	35	65
5411	-	10	-
2912	15	25	60
4X14	20	50	85
5413	15	35	65
2914	10	30	40
4X18	15	40	60

The best growth was observed in provenances 5420, 5813, 6313, 6531, OX03, 7213, 7221 and 4X14, mainly from Mid-Europe (Codes 4&5), France and Switzerland (Code 6) and Yugoslavia (Code 7).

These results may be influenced by the different rates of germination, but the effect will probably diminish with time, for example after a season's growth in 1982.

6.8 Proposed Work

Winter 1982

- Start in the greenhouse those provenances which either did not grow, or only grew a little.
(eg. 2144, 2612, 2634, 2652, 2812, 5813, 6313, 6365, 6523, 6531, OX03, 7242, 2163, 7213, 7221, 2811, 1721, 4714, 5621, 6535, 4X31, 5411)

These repeats are necessary in order to obtain sufficient numbers of trees for later measurements of growth and hardiness.

- Start the alder provenances received from Dr. Weisgerber's seed bank in Germany (Tables 20 and 21).

Spring 1982

- Assess hardiness characteristics in the field (eg. date of leaf emergence, susceptibility to late frost and winter cold, and winter mortality).

Autumn 1982

- Measure the height and diameter growth in the field.

Table 20 Provenances from Dr. Weisgerber's Seed Bank
(1979/80) in Germany

<u>Alnus glutinosa</u>			<u>Quantity</u>
1. Herk.: Hess. Bergland			
Me	1	20 g	
Me	3	"	
Me	5	"	
Me	6	"	
Me	9	"	
Me	10	"	
Me	11	"	
Th	4	"	
Th	6	"	
Th	7	"	
			= <u>200 g</u>
2. Herk. : Ostpreuben			
SW	2	20 g	
SW	3	"	
SW	4	"	
SW	5	"	
SW	6	"	
SW	8	"	
SW	9	"	
SW	10	"	
SW	11	"	
SW	12	"	
			= <u>200 g</u>
3. Herk.: Bayr. Tieflagen			
Rott	1	20 g	
Rott	7	"	
Rott	9	"	
Rott	10	"	
Rott	11	"	
			= <u>100 g</u>
Total			<u>500 g</u>

Table 21 Banks of Seed of Alder Provenances (Alnus glutinosa)

A. Richard B. Hall
Iowa State University
Department of Forestry
251 Bessey Hall
Ames, Iowa 50011
USA

Telephone: 515-294-1166

B. Dr. H. Weisgerber
Forstdirektor
Forschungsinstitut für
Schnellwachsende Baumarten
Prof. - Oelkers - Str. 6
3510 Hann.
Münden 1

Telephone: 05541-4187

7. TRANSFER OF FIXED NITROGEN FROM ONE TREE SPECIES TO ANOTHER
BY COMMON ECTOMYCORRHIZAL MYCELIA (DR. MICHEL COUTURE)

In 1979, it was decided to examine whether or not ectomycorrhizae play an important role in the circulation in forest soils of nitrogen fixed by Frankia. More specifically, research was designed to confirm or disprove the hypothesis that some of the nitrogen fixed by an actinomyco-rhizal plant may be translocated to a non-actinorhizal plant through the soil phase via the hyphae of ectomycorrhizal fungi.

The work was carried out using plastic growth pouches in controlled environment chambers. The first attempts were made with Alnus glutinosa and Pinus strobus as the tree species, Frankia as the nitrogen-fixing actinomycete, and Pisolithus tinctorius as a fungus potentially capable of forming mycorrhizae on trees.

The technique of growing Alnus glutinosa and Pinus strobus in growth pouches has been mastered.

Attempts to create mycorrhizal symbioses with these trees and the fungus Pisolithus tinctorius were also successful. The mycorrhizae formed more easily on the pine than the alder, and on the latter the intensity of mycorrhization of the roots was less than on the pines. The alder readily formed actinorhizal nodules.

This research, which is closely related to the search for more effective ectomycorrhizal fungi described elsewhere in this report, presents many challenges. Simultaneous formation of mycorrhizae on alder and pine has been achieved but mycorrhizae formation still poses problems that indicate a need to modify the technique.

A problem that has arisen is that the pine does not grow well when

intimately associated with the alder in the same pouch, even though there are preliminary indications that nitrogen is being taken up by the pine. After three months the foliage weights of pine growing in a pouch with or without alder were almost identical.

The weights of the roots of pine grown with alder were, however, much lower than those growing alone. Also leaves of pines grown with the alder had lower concentrations of nitrogen than the roots.

It is possible that the exudates from the alder roots in some way inhibit the development of the roots of the companion pine plant.

All these problems indicate that the techniques should be revised. A twin pouch technique will be used to reduce the chance of the acid exudates from the alder roots harming the pine development.

In addition a new, and possibly better, ectomycorrhizal fungus (Paxillus sp.) will be used. This fungus appears to form mycorrhizae with equal intensity on both the alder and the pine.

Parallel to this work, a hermetically enclosed chamber will be used together with pine plants containing ^{15}N as a stable isotope marker to trace the nitrogen path ways.

This work was scheduled to end by March 31st 1982 but, since most of the work on selection of ectomycorrhizae, selection of Frankia and development of a new pouch technique has been done, it is suggested that the research is continued to the end of the contract.

Initially it was intended that the transfer of fixed nitrogen by ectomycorrhizal hyphae would be studied in forest soils in field conditions. A great deal of thought has been directed at this area. It is suggested that in view of the difficulties encountered in the laboratory in confirming

ectomycorrhizal transfer of fixed nitrogen, to study this process in the field would be premature. It would be more rewarding to direct the effort to other parts of the project.

8. THE CYCLING OF NITROGEN AT DIFFERENT TREE SPACINGS (DR. CLAUDE CAMIRE AND MR. ROLAND CAMIRAND)

8.1 Introduction

An experiment designed to evaluate the day-to-day biological interactions of mixed plantations consisting of tree species with nitrogen fixing symbioses and tree species without has been established on half of the prepared site at the disposal of the program on the Laval University Campus.

The whole plot is 0.5 ha (73 m X 74 m). A 4.9 m X 6.1 m building equipped with water and electricity was established on the site which was later fenced. These capital costs were met by the Quebec Minister of Education's FCAC fund, and from the University's budget. The soil is a loam formerly supporting hardwood forest. This work is only partly funded by ENFOR.

8.2 The objective

The objective of the ENFOR research is to observe from day-to-day the nitrogen cycle in plantations of actinorhizal and non-actinorhizal tree species at different spacings, in order to provide a sound basis for future management. The results should give an idea of quantities of nitrogen fixed both in symbiotic and non-symbiotic situations.

8.3 Tree species used in the experiment

Initially Alnus rugosa and the hybrid poplar "Roxbury" were chosen to be used in the experiment, but Alnus rugosa presents production problems and it was necessary to change the alder component to wild plants of

Alnus glutinosa. The hybrid poplars were raised as cuttings. Table 22 explains the details of plant production.

8.4 Experiment design

The total area of the experiment is 2232 m^2 (62 m X 36 m). Within the area are 72 plots each 5 m X 5 m, laid out as illustrated in Figure 3 with 2 m wide access paths.

There were two treatments, a) proportions of tree species, and b) tree spacing. Two species were used, alder and hybrid poplar as described above.

Three spacings were used, namely 100 X 100 cm, 66 X 66 cm and 33 X 33 cm, requiring 25 trees per plot (10000/ha), 49 trees per plot (22500/ha) and 225 trees per plot (90000/ha) respectively.

The proportions of alder and poplar used were 0-3, 1-2, 2-1, and 3-0. The first is all poplar, the second 1 alder to 2 poplars, and so on.

The design is factorial, with 12 treatments (3 X 4), and six replications, giving a total of 72 plots. The 12 treatments are illustrated in Figures 3 to 15.

8.5 Planting the experiment

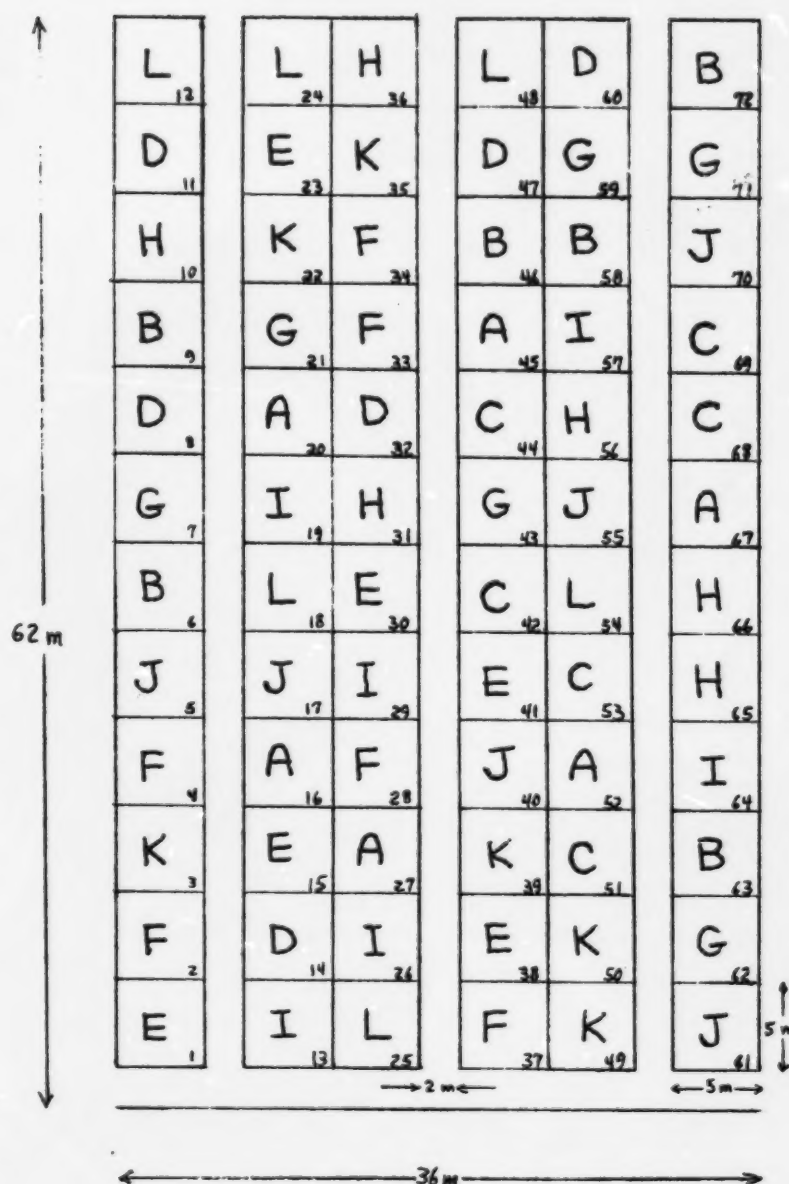
The planting started on 20th May 1981 and took 3 days. In the following days the trees were well watered. Surplus trees were established in a small temporary nursery to provide a bank of material to replace failures in the plots.

8.6 Soil sampling and analysis

Before the site was planted, soil samples were collected from each of the plots for analysis. Samples consisted of ten sub-samples per plot from the top 0-15 cm and thoroughly mixed to form a composite sample. The analysis will be carried out in the winter of 1982.

Table 22 Characteristics of the plants produced

Species	Method of propagation	Provenance	Conditions of production	Quantity
<u>Populus X hybrid</u>	Cuttings	Hybrid "Boxbury" - nursery des Cimes, Neufchatel, Québec	Styroblocks - Winter 1981	5000
<u>Alnus glutinosa</u>	Wild plants	Villeroy, Québec	Natural 1 to 2 years old	3700



Total: $62 \times 36 \text{ m} = 2232 \text{ m}^2$
 Plots: $25 \text{ m}^2 \times 72 = 1800 \text{ m}^2$
 Access: $(2 \times 3 \times 60) + (2 \times 36) = 432 \text{ m}^2$

FIGURE 3

The complete layout. The types of plots A - L described in Figures 4 - 15

Ⓐ

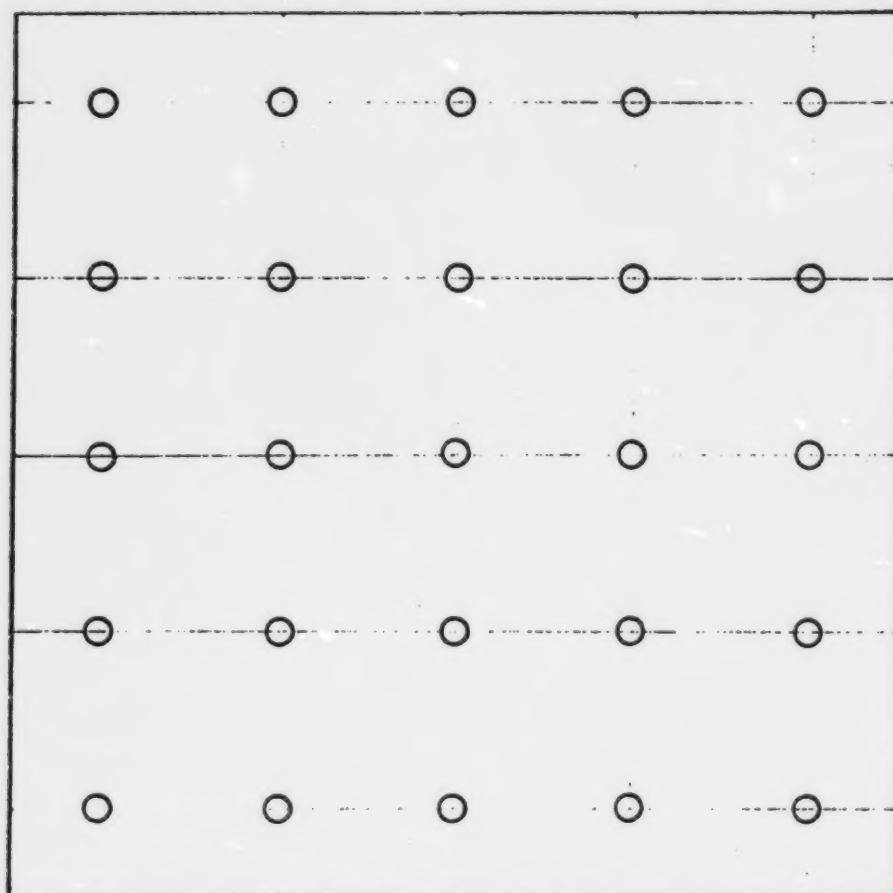


Figure 4

Type: A Spacing: 100 x 100 cm

Density: 10000/ha

ALDER POPLAR TOTAL

Ratio: 0 3

Number: 0 25 25

△ ○

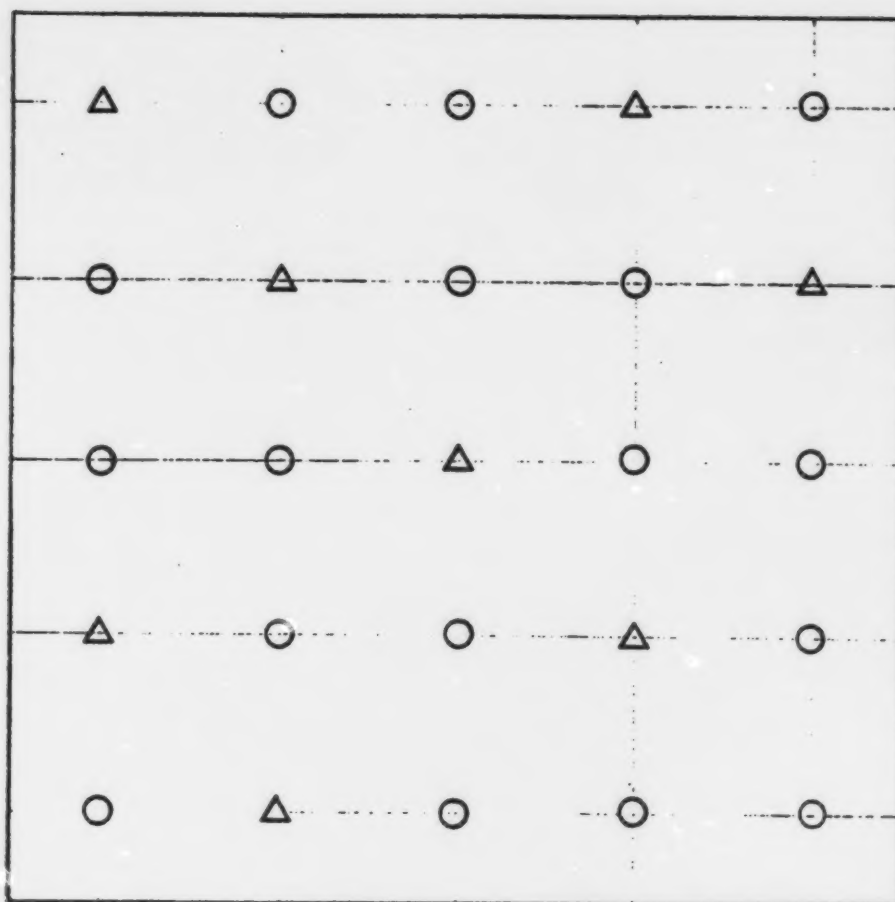


Figure 5

Type: B Spacing: 100 x 100 cm

Density: 10000/ha

	ALDER	POPLAR	TOTAL
Ratio:	1	2	
Number:	8	17	25
	△	○	

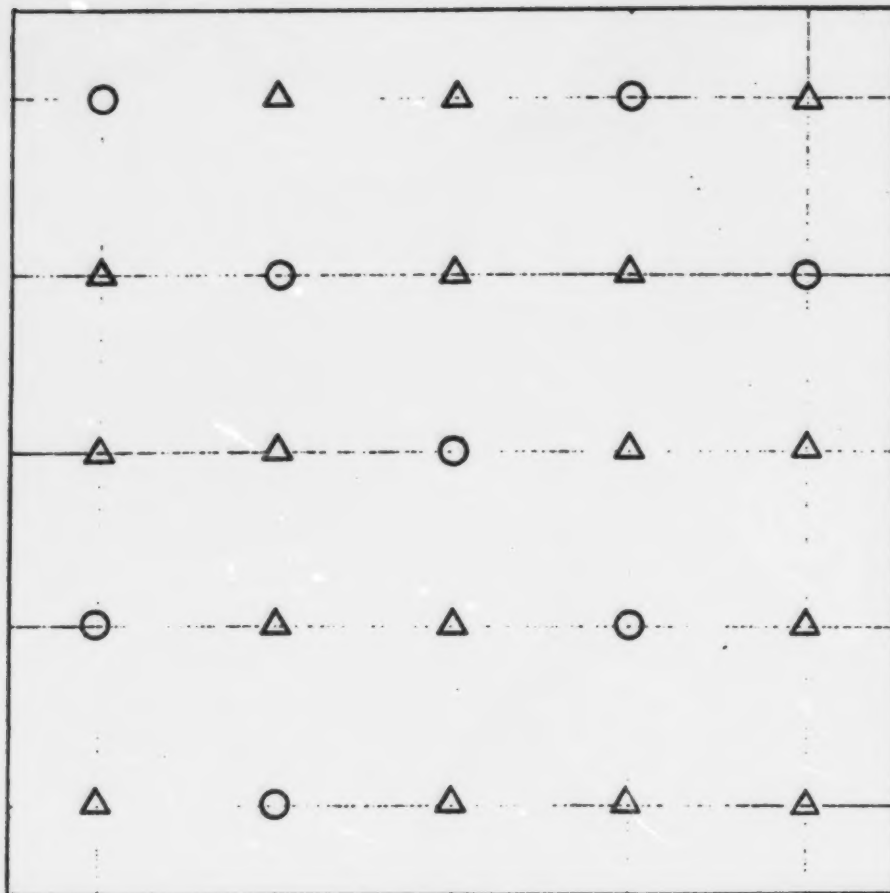


FIGURE 6

Type: C Spacing: 100 x 100 cm

Density: 10000/ha

	ALDER	POPLAR	TOTAL
Ratio:	2	1	
Number:	17	8	25
	△	○	

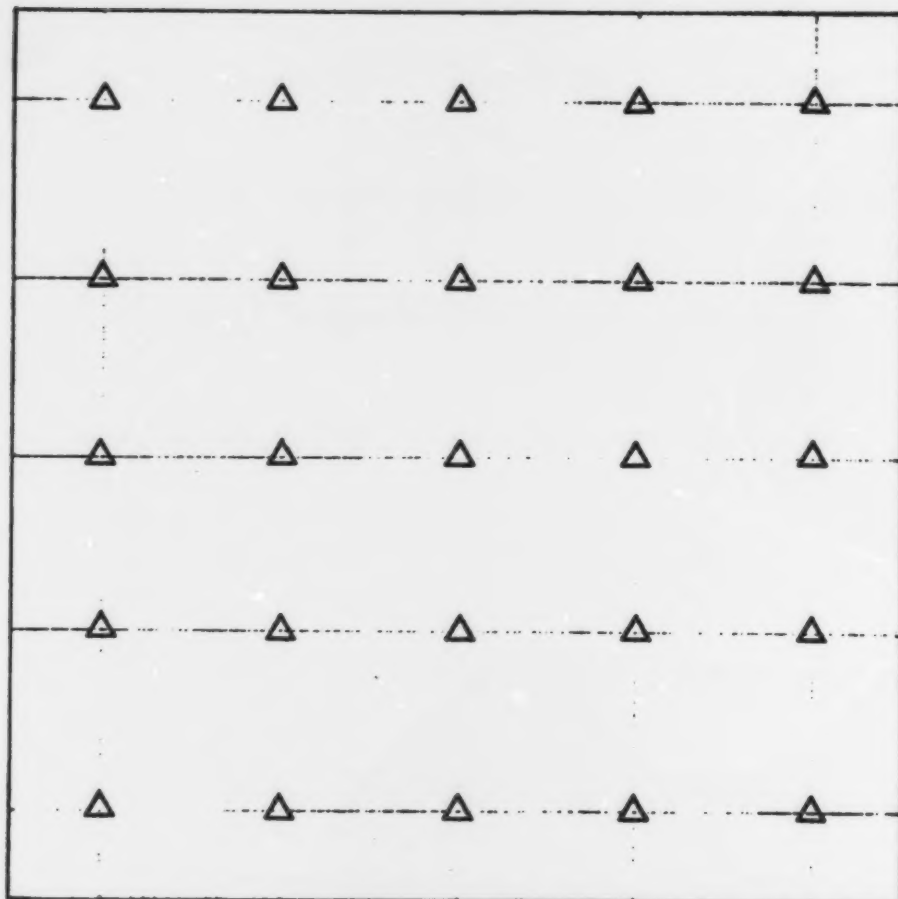


FIGURE 7

Type: D Spacing: 100 x 100 cm

Density: 10000/ha

	ALDER	POPLAR	TOTAL
Ratio:	3	0	
Number:	25	0	25
	△	○	

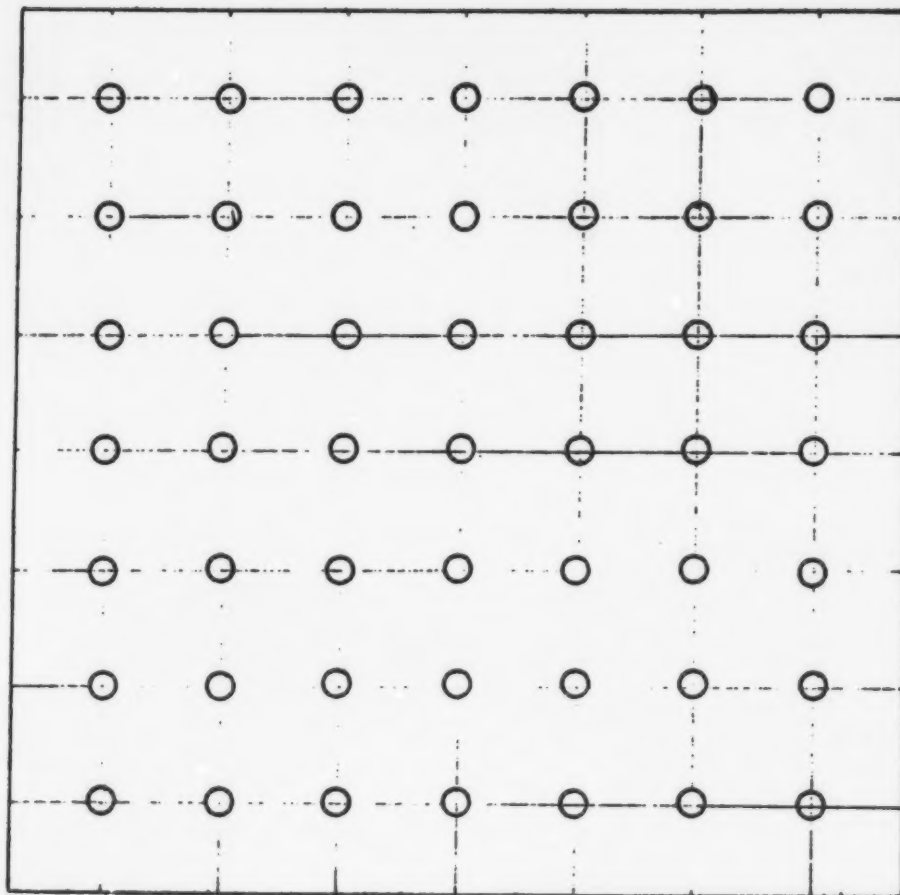
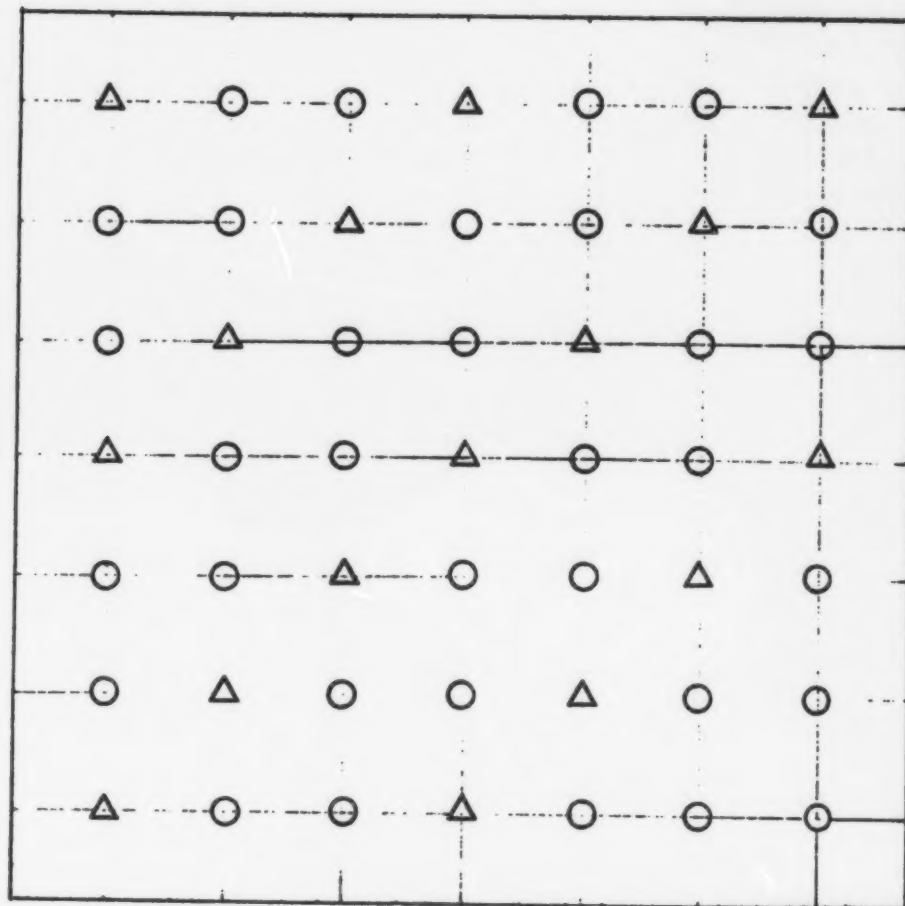


FIGURE 8

Type: E Spacing: 66 x 66 cm

Density: 22500/ha

	ALDER	POPLAR	TOTAL
Ratio:	0	3	
Number:	0	49	49
	△	○	



(F)

FIGURE 9

Type: F Spacing: 66 x 66 cm
Density: 22500/ha

	ALDER	POPLAR	TOTAL
Ratio:	1	2	
Number:	16	33	49
	△	○	

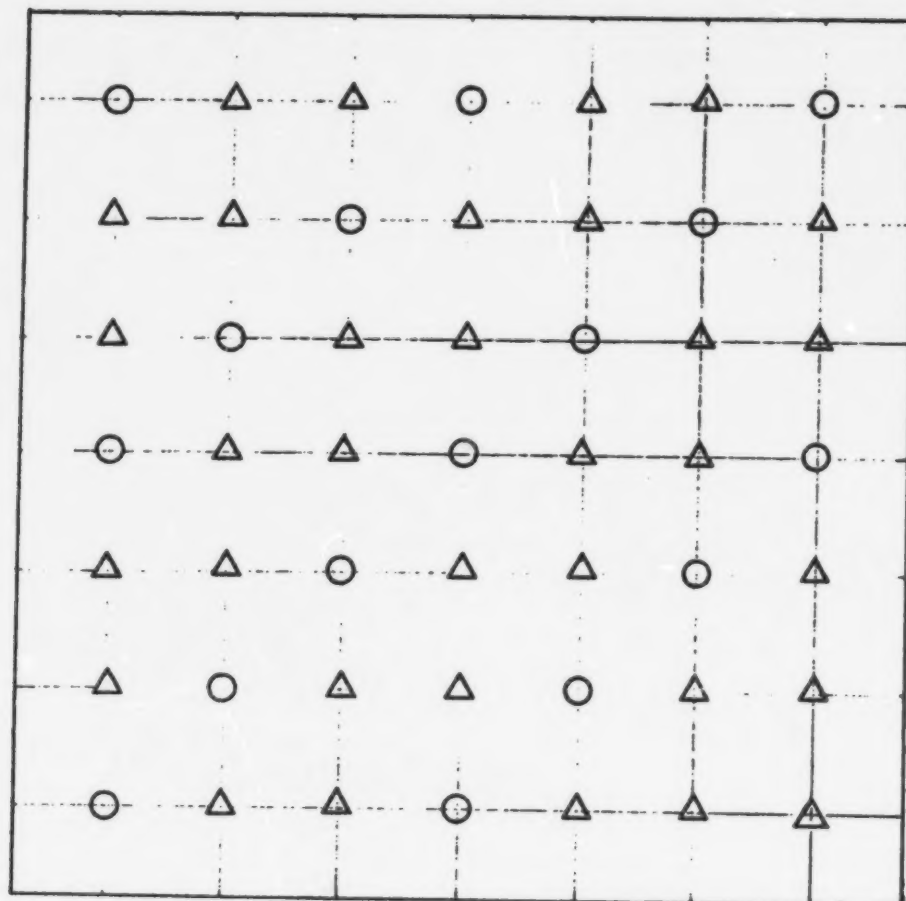


FIGURE 10

Type: G Spacing: 66 x 66 cm

Density: 22500/ha

	ALDER	POPLAR	TOTAL
Ratio:	2	1	
Number:	33	16	49
	△	○	

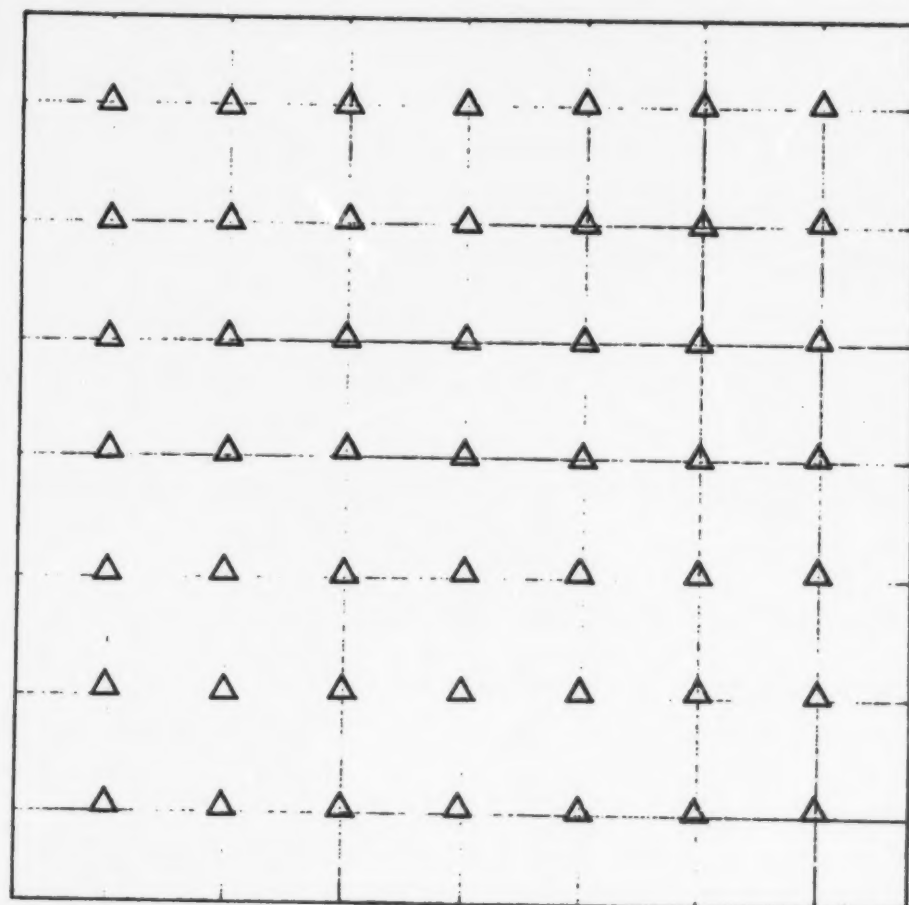
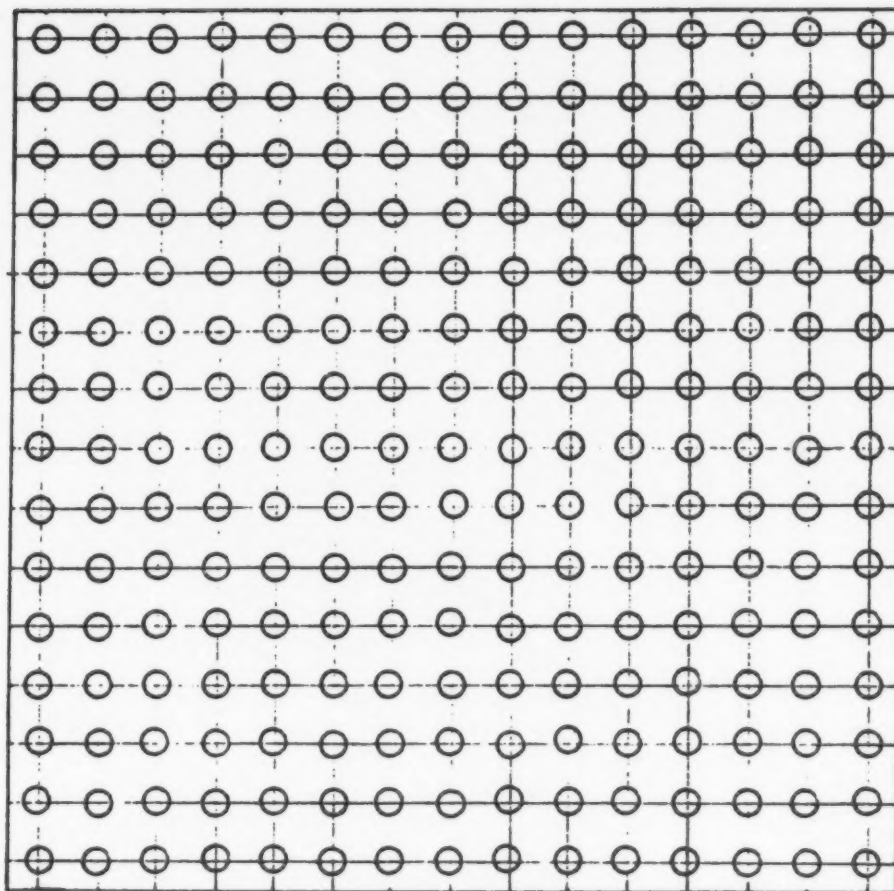


FIGURE 11

Type: H Spacing: 66 x 66 cm

Density: 22500/ha

	ALDER	POPLAR	TOTAL
Ratio:	3	0	
Number:	49	0	49
	△	○	



I

FIGURE 12

Type: I Spacing: 33 x 33 cm

Density: 90000/ha

	ALDER	POPLAR	TOTAL
Ratio:	0	3	
Number:	0	225	225
	△	○	

J

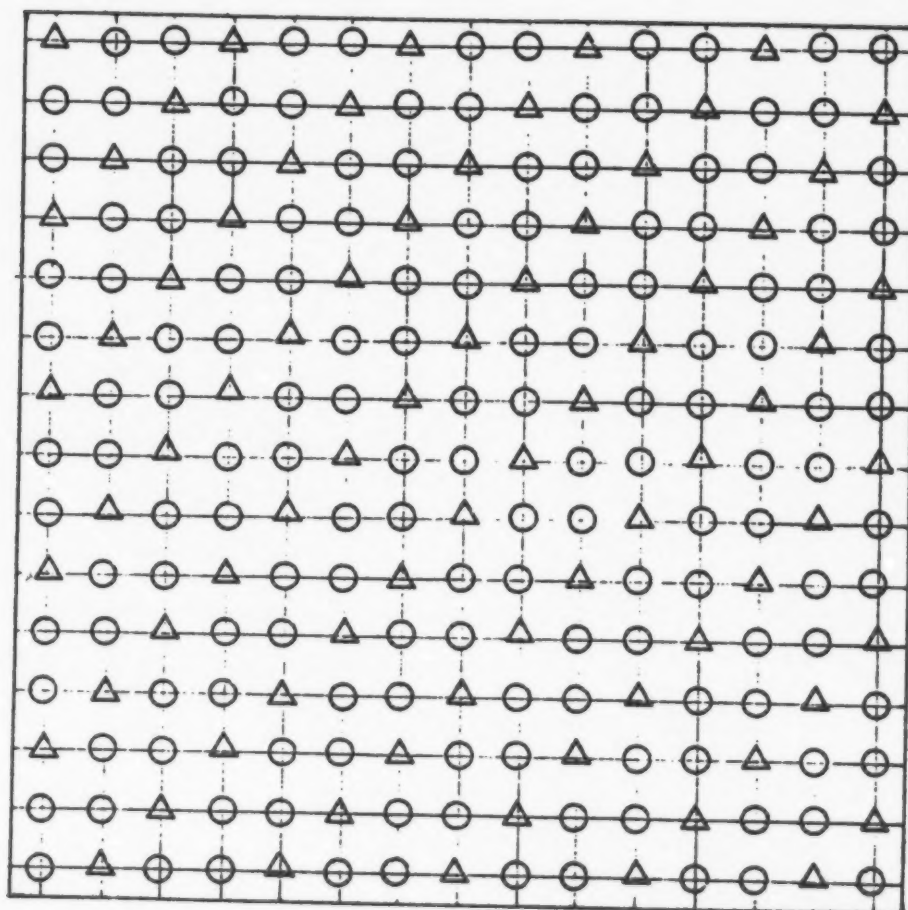


FIGURE 13

Type: J Spacing: 33 x 33 cm

Density: 90000/ha

	ALDER	POPLAR	TOTAL
Ratio:	1	2	
Number:	75	150	225
	△	○	

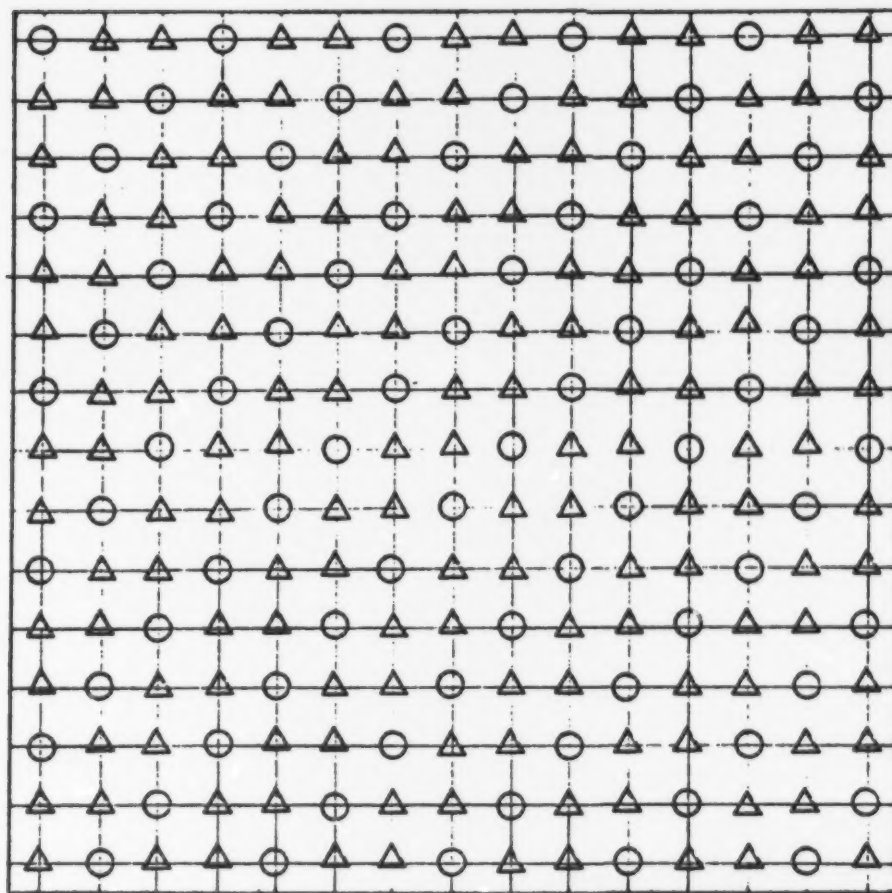


FIGURE 14

Type: K Spacing: 33 x 33 cm

Density: 90000/ha

	ALDER	POPLAR	TOTAL
Ratio:	2	1	
Number:	150	75	225
	Δ	○	

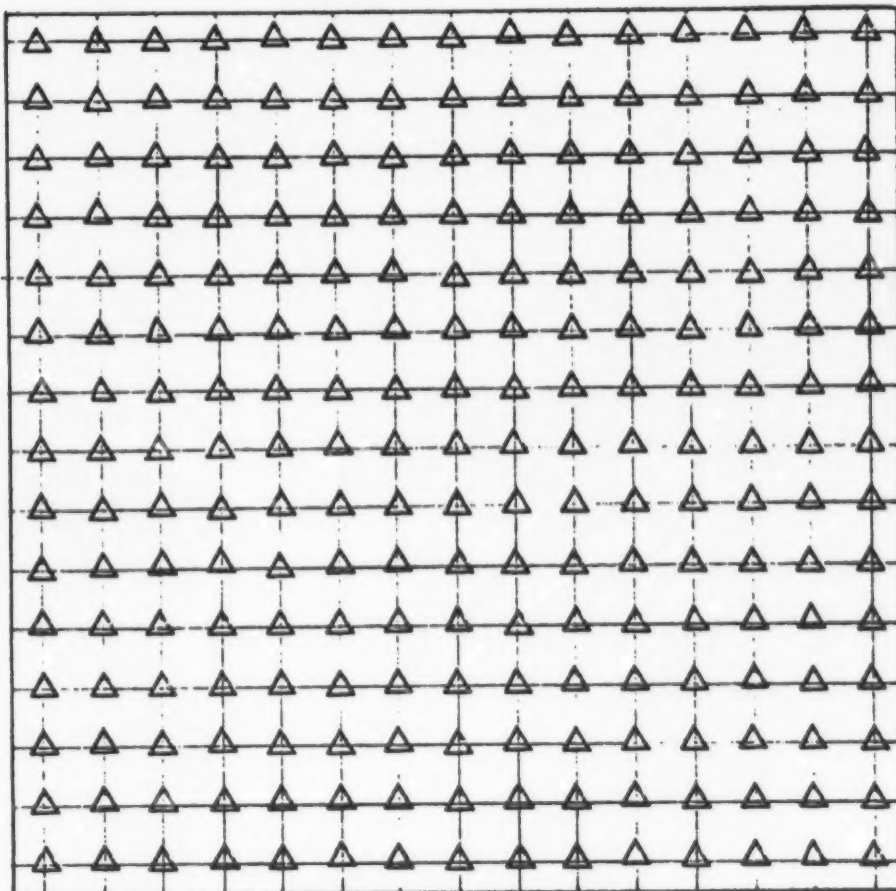


FIGURE 15

Type: L Spacing: 33 x 33 cm

Density: 90000/ha

	ALDER	POPLAR	TOTAL
Ratio:	3	0	
Number:	225	0	225
	△	○	

8.7 Weed control and plant replacement

The first task was to remove the weeds mechanically in the plots to permit the survival of young plants and cuttings. This work was very time consuming especially in the plots with high tree density.

By the end of June 1981, alder trees that had failed had been replaced. In the case of the poplar, the work was completed by the end of August 1981.

Mortality and replacement of the two tree species are described in Table 23. Alder mortality was 12.5% and poplar 40.6%. The high poplar mortality and the limited supply of replacement plants means that two of the six replications will need to be eliminated from the experiment.

Poor plant production is possibly the cause of these losses. The poplar cuttings obtained from a private nursery were produced in styroblocs at the end of January 1981 and then into the ground in May 1981. The majority of the cuttings did not retain a root system and some of the cuttings were too old, with very few buds.

In order to solve the problems arising from these losses, the experimental design was modified by eliminating the 5th and 6th replicates and using the plants to replace those lost in other parts of the experiment. This modification is illustrated in Figure 16.

8.8 Installation of tension lysimeters

Tension lysimeters were installed in the centre of 15 plots (Nos. 46 to 60 in Figure 16) at a depth of 30 cm. The lysimeter is manufactured by the Soil Moisture Equipment Company of Santa Barbara, California, USA, consists of a ceramic cup connected to polyvinyl (PVC) tube.

The ceramic cup has a bubbling pressure of 2 bars with an outside

Table 23 Mortality of poplar and alder in the experiment

Species	Quantity (planted)	Mortality (%)	Quantity ^{1/} (replacement)	Quantity ^{2/} (nursery)	Solution adopted
<u>Populus X hybrid</u>	3563	40.6	972	200	Removal of two replicates
<u>Alnus glutinosa</u>	3563	12.5	300	75	Collect new wild plants

1/ Quantity assessed after the removal of two replicates

2/ Final quantity of healthy plants

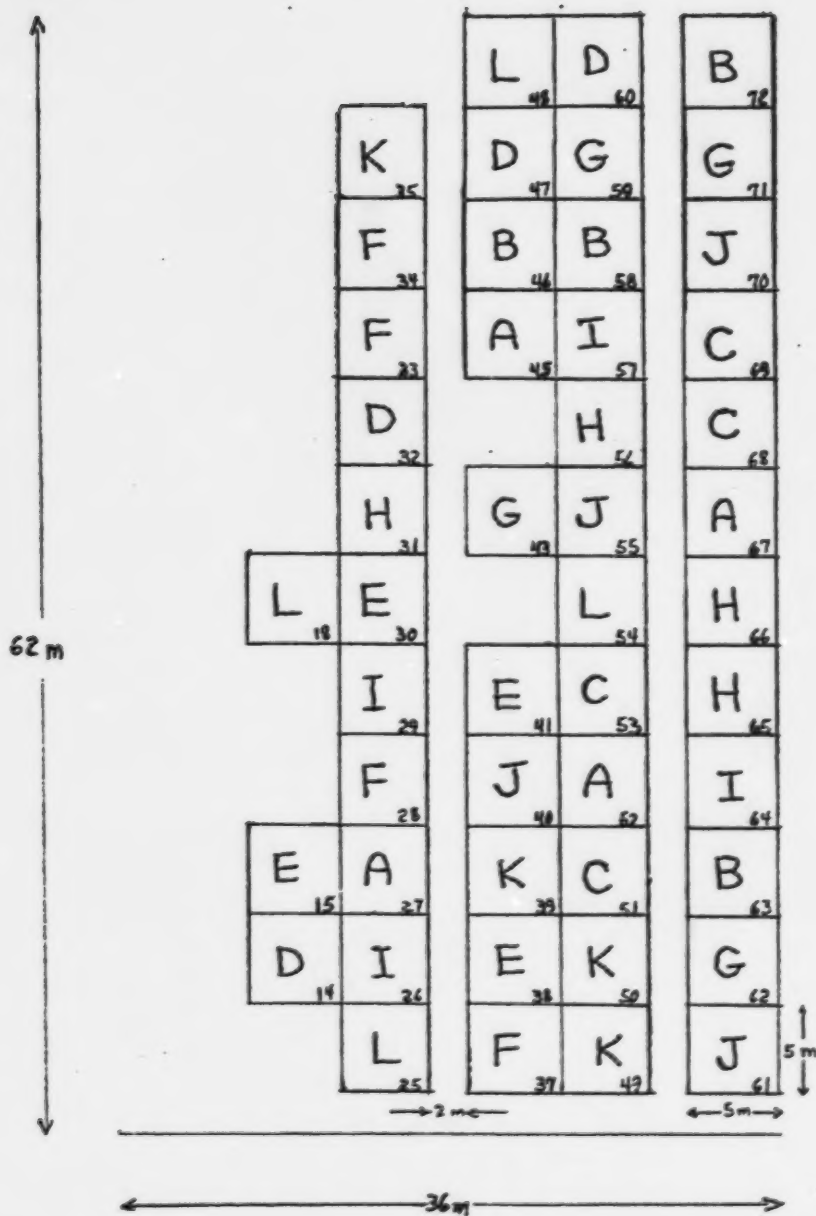


FIGURE 16

The modified design. The types of plots (A-L) are explained in Figures 4-15.

diameter of 49.5 mm, an exposed length of 61 mm and a ceramic thickness of 2 to 3 mm.

The first water collections will be made in the spring of 1982, which will allow time for the soil to make good contact with the wall of the ceramic cup.

8.9 Proposed work 1982

a) Winter 1982

- Analyse the soil samples from each plot

b) Spring 1982

- Install lysimeters in other plots
- Install a complete meteorological station
- Install gauges to collect throughfall water in each plot

c) Spring -Summer 1982

- Collect the samples from each of the lysimeters and rain gauges
- Analyse the soil water, throughfall and rainfall in the laboratory

d) Autumn 1982

- Collect the litter in each plot
- Analyse litter, soil water, throughfall and rainfall in the laboratory.

9. ALLELOPATHIC INTERACTIONS BETWEEN ALDER, POPLAR, AND FRANKIA

Recent work carried out on the harmful effects of phenolic compounds from balsam poplar on the nodulated and unnodulated seedlings of Alnus crispa have provided information that permits the design of cultural methods to give better yields when the poplar and the alder are grown together in mixed plantations to produce biomass. The principal results obtained so far are described below.

9.1 Allelopathic substances of balsam poplar (Populus balsamifera) and the germination of Alnus crispa seeds

Very low concentrations of the allelopathic substances in leaf leachates and aqueous extracts from the buds of balsam poplar strongly affected the germination of Alnus crispa seeds. The leachates and extracts significantly reduced the germinative capacity, inhibited the formation of absorbant root hairs, caused meristematic necrosis, and reduced hypocotyl development.

During this research it was found that the alder seed coats could be surface sterilized efficiently using merthiolate. Use of sodium hypochlorite or hydrogen peroxide was less effective. Details are reported in the Master's Thesis by R. Jobidon (1982) entitled "Contribution à l'étude des composés allélopathiques du peuplier baumier". Laval University Graduate School.

9.2 Allelopathic substances of balsam poplar and the development of nodulated and non-nodulated seedlings of Alnus crispa

Wherever short rotations of poplar plantations are used they will make great demands upon the soil, particularly on soil nitrogen reserves.

Using nitrogen-fixing actinorhizal symbioses, such as occur between Frankia and alders, as well as Rhizobium and legumes, would appear to be a way of maintaining soil nitrogen levels that is preferable to reliance on expensive, energy demanding chemical fertilizers. In order to manage these intensively managed mixed plantations effectively the interaction between the poplars and the nitrogen-fixing species must be understood.

Alders are known to have a high nitrogen-fixing potential (100 to 250 kg/ha/year), and could be of great value in soil management when we learn how to handle them. The degree of nodulation by the nitrogen-fixing

actinorhizal symbiont, Frankia, of the alder plants determines to a great extent the quality of nitrogen the alders can fix. It is important, therefore, that the effect of the poplars and other factors on alder nodulation is understood if the two genera, Populus and Alnus are to be used as companion species in mixed plantations.

So far it has been found that substances occur in very low concentrations in aqueous extracts of fresh leaves of balsam poplar that affect alder nodulation, the activity of nitrogenase (the enzyme essential to the nitrogen-fixing process) and the development of Alnus crispa seedlings.

Specific effects observed in the laboratory so far are as follows:

- (a) A marked (up to 49%) reduction in the height growth of the alder shoots.
- (b) A marked reduction in the elongation of the roots.
- (c) A marked (up to 64%) reduction in the dry weight of the seedlings.
- (d) A significant reduction (up to 16%) in the concentration of nitrogen in the leaves.
- (e) Better tolerance of nodulated plants to treatment with the extracts compared with non-nodulated plants.
- (f) A reduction of up to 58% in the number of nodules on alder seedlings treated with the poplar extracts compared with the untreated controls.
- (g) A reduction of about 62% in nitrogenase activity (measured by the acetylene reduction method) on alder seedlings treated with the poplar extracts compared with the controls.

9.3 Identification of the poplar leachates

Analysis of the leachates phenolic compounds involved in the poplar-alder interactions described above indicate that the leachates contain simple phenolic acids of the cinnamic and benzoic series. Details are given in the Master's Thesis by Y. Perradin of Laval University, entitled:

"Caractérisation phytochimique et impact des composés phénoliques du peuplier baumier sur l'actinorhize aulne-Frankia", at present in draft form.

The phenolic acids involved are as follows:

Cinnamic Series	Benzoic Series
Para-coumaric	Gallic
Meta-coumaric	Salicylic
Caffeic	Protocatechuic
Trans-cinnamic	Benzoic
Ferulic	Syringic
Chlorogenic	Para-hydroxy-benzoic
	Gentisic
	Ellagic
	Vanillic

9.4 Effects of endogenous phenols in the alder on the activity of Frankia

The study of the effect of simple phenols found within the alder tissues on Frankia activity was studied in a plastic pouch containing the Frankia strain ACN1^{AG}. It was found that:

- (a) Phenolic acids of the benzoic series induced vesicles to form on the Frankia. There was moderate inhibition by the acids of both growth and sporulation of the actinomycete.
- (b) Phenolic acids of the cinnamic series very strongly inhibited growth, modified the hyphae, strongly inhibited sporulation and had no apparent effect on the vesicles.

The results are described in detail in a manuscript prepared for publication by Perradin Y., M. Lalonde and J.R. Thibault provisionally entitled: "Effect of endogenous phenolic compounds of Alnus crispa var. mollis Fern. on the biology of Frankia".

The evidence so far suggests allelopathic inhibition of Alnus crispa by balsam poplar is possible, but more research is needed in field

conditions where these effects can be studied in relation to other ecological factors such as light, soil water and soil nutrients. The better response of nodulated alder seedlings to allelopathic treatment compared with unnodulated seedlings is interesting. We still need to understand the mechanism involved.

The research on allelopathy in alders and poplars is partly supported by ENFOR and partly by the National Research Council and the Quebec Government's FCAC program.

10. SURVIVAL OF FRANKIA SYMBIONTS IN THE FIELD (DR. MAURICE LALONDE AND MR. DARWIN BURGESS)

In the Laval program Frankia symbionts have been selected and stored for future use. This work is described elsewhere in this report. It is necessary to determine whether or not selected actinorhizal symbionts can survive competition by other soil organism in the field.

With this in view, a joint experiment was established at Laval University (Dr. Maurice Lalonde and Mr. Darwin Burgess). There were three objectives (a) to establish a bank of tree species capable of forming nitrogen-fixing symbioses with Frankia to examine their growth and survival in the Petawawa, Ontario region, and (b) to use the survivors to provide a future source of vegetation propagules for research and subsequent operational use. (c) to assess the survival of Frankia symbioses in the field.

10.1 Tree and shrub species

The seed of 10 alder species and two Elaeagnus were obtained and sown in the greenhouse in a nitrogen-free medium. After germination half were inoculated, and half were not as controls. The species involved are listed in Tables 24-25. 25 seeds were sown in each pot to be inoculated, and

Table 24 The alder and Elaeagnus species used in the experiment

Species
<u>Alnus cremastogyne</u> Burk.
<u>A. crispa</u> (Ait.) Pursh. (American Green Alder)
<u>A. glutinosa</u> (L.) Gaertn. (Black Alder)
<u>A. hirsuta</u> Spach. Ruprecht.
<u>A. incana</u> (L.) Moench (Grey Alder)
<u>A. japonica</u> (Thumb.) Steud. (Japanese Alder)
<u>A. rubra</u> (Du Roi) Spreng. (Speckled Alder)
<u>A. sinuata</u> (Reg.) Rydb. (Sitka Alder)
<u>A. viridis</u> (DC.) (European Green Alder)
<u>Elaeagnus angustifolia</u> (Russian Olive)
<u>E. commutata</u> (Snowberry)

Table 25 Provenances of Alder and Elaeagnus

Species	Origin		
	Site	Latitude	Longitude
<u>Alnus crispa</u>	Chapeau, Ont.	47N	83W
<u>A. cremastogyne</u>	China	29N	104E
<u>A. glutinosa</u>	Penzenskoi Oblast USSR	53N	43E
<u>A. hirsuta</u>	Scotland	(56N)	(4W)
<u>A. incana</u>	Eganville, Ont.	45N	77W
<u>A. japonica</u>	Perthshire, Scotland	(56N)	(3W)
<u>A. rubra</u>	Forbidden Plateau, B.C.	49N	125W
<u>A. sinuata</u>	Prince Rupert, B.C.	54N	126W
<u>A. rugosa</u>	PNFI Chalk River, Ont.	45N	77W
<u>A. viridis</u>	Perthshire, Scotland	(56N)	(3W)
<u>Elaeagnus</u>	North Dakota, USA	(46N)	(100W)
<u>angustifolia</u>			
<u>E. commutata</u>	Saskatchewan	-	-

() = approximate

25 in the control. Low germination was a problem. All were watered with an N-free mineral solution.

10.2 Frankia inoculation

The four Frankia inoculants were selected and cultured by Dr. Lalonde at Laval University. They were:

Frankia ACNI^{AG} (10 tubes). For use on Alder

Frankia AGNI^{AG} (10 tubes). For use on Alder

Frankia EANI_{pec} (2 tubes). For use on Elaeagnus

Frankia EUNI_fS20 (2 tubes). For use on Elaeagnus

All strains were cultivated on 17th March 1981 on Q mod B nutrient medium.

They were sent to Petawawa N.F.I. in 24 Vacutainer tubes.

At Petawawa each Frankia colony in its Vacutainer was broken into small fragments, using a 3 mL syringe and a 21 G needle, by flushing 10 times or more.

After colony breakage, the Frankia ACNI^{AG} and AGNI^{AG} filaments and liberated spores were resuspended in 95 mL of the N-free mineral solution used to water the plants. 2 mL of the inoculum was applied to each seedling. The EUNI_fS20 and EANI_{pec} cultures were resuspended in 45 mL of the mineral-free solution. Each Vacutainer tube contained enough inoculant for 50 alder seedlings (ACNI^{AG} and AGNI^{AG}) and 25 Elaeagnus seedlings (EANI_{pec} and EUNI_fS20).

The ACNI^{AG} strain was isolated from Alnus crispa at Tadoussac, Quebec. The AGNI^{AG} came from Alnus crispa in the Netherlands. EANI_{pec} came from Elaeagnus angustifolia in Ohio, and EUNI_fS20 from Elaeagnus umbellata in Illinois.

10.3 Inoculated plant performance

The results of this preliminary trial are given in Table 26.

Table 26 . Alder seedling inventory - Petawawa N.F.I., Ont. Summer 1981

Species	Control		Inoculum AGNI ^{2/}		Inoculum AGNI ^{2/}	
	No. of Seedlings	Average Ht. cm	No. of Seedlings	Average Ht. cm	No. of Seedlings	Average Ht. cm
1. <u>Alnus cremastogyne</u>	32	16.2	15	20.8	16	18.1
<u>Alnus cremastogyne</u>	186	19.8				
2. <u>Alnus crispa</u>	30	6.7	16	8.4	15	9.9
<u>Alnus crispa</u>	149	4.5				
3. <u>Alnus glutinosa</u>	44	16.2	16	14.1	24	19.0
<u>Alnus glutinosa</u>	62	20.7				
Extra control	12	19.3				
4. <u>Alnus hirsuta</u>	1	9.5	0	0	0	0
<u>Alnus hirsuta</u>	0	0				
5. <u>Alnus incana</u>	31	13.8	15	13.9	17	15.6
<u>Alnus incana</u>	279	15.6				
Extra control	3	5.0				
6. <u>Alnus japonica</u>	32	13.8	16	18.4	16	15.9
<u>Alnus japonica</u>	193	26.8				
7. <u>Alnus rubra</u>	30	9.4	16	11.9	16	14.3
<u>Alnus rubra</u>	170	22.3				
Extra control	1	14.5				
8. <u>Alnus rugosa</u>	23	10.0	16	10.6	6	12.2
<u>Alnus rugosa</u>	167	16.9				
Extra control & AGNI	10	9.9			1	3.5
9. <u>Alnus sinuata</u>	12	4.2	5	4.1	6	4.1
<u>Alnus sinuata</u>	137	7.7				
Extra control and AGNI and AGNI	13	5.0	2	3.2	10	8.6
No tag (planted same as AGNI)					7 ^{1/}	1.8 ^{1/}
10. <u>Alnus viridis</u>	5	3.2	6	4.2	6	4.2
<u>Alnus viridis</u>	30	3.8				
Extra control AGNI and AGNI			8	1.6	7	6.0

1/ Not confirmed as AGNI

2/ All alder seeds that germinated were successfully inoculated and the plant survived.

Only alder results are given, because the inoculation of the Elaeagnus was unsuccessful.

The reasons for the Elaeagnus inoculation failure are not completely understood, but it is likely that the Frankia strains from Elaeagnus were very sensitive to the conditions they were exposed to during transport.

10.4 Work for 1982

During 1982 Elaeagnus seed will be sent from Petawawa N.F.I. to Laval University. The seedlings will be raised and inoculated at Laval and later used in the Petawawa experiment.

A new set of 10 Alder species will be sown at Petawawa. These will include Alnus crispa, A. firma hirtella, A. cordata, A. glutinosa, A. incana, A. japonica, A. maximowiczii, A. rubra, A. rugosa, A. sinuata and A. tenuifolia. A seed lot of Hypophae rhamnoides will also be sown, as well as lots of Elaeagnus angustifolia and E. commutata. These will be sown, inoculated and tested in the field.

11. SCIENTIFIC OUTPUT FROM THE ENFOR CONTRACTS

The scientific output from the ENFOR programme on the use of actinorhizal and mycorrhizal symbioses in forestry has been in both tangible and intangible forms. The tangible products are the reports on new techniques and scientific results written to fulfill the contract. The intangible effects of the work are concerned with education, training and scientific attitude which reach far beyond the stated contractual objectives.

11.1 Tangible productivity

The tangible results obtained so far from the ENFOR P-78 and P-198 contracts are described in this report and the previous reports for the 1979 - 80, 1980 - 81 and the current 1981 - 82 periods. They include the

development of new techniques; the selection of actinorhizal and ecto-mycorrhizal symbionts; the development of a tested Frankia culture and inoculation technology ready for operational use; establishment of field experiments to examine the interactions and effects of alder and other tree species; testing of alder species and provenances, culturing alder from tissues in vitro, and many other results.

This work has engendered a much better understanding of the symbionts and how to manipulate and use them. Before this program very little was known about Frankia either within the forestry context or outside it.

This new knowledge is particularly timely in view of the national, and indeed, world wide interest in using microorganisms in an energy efficient manner to provide goods and services, usually called "biotechnology".

Microorganisms will be used much more widely by industry, and forestry will be no exception. There will be opportunities to use biological techniques of forest soil management within the context of intensive forestry, and this ENFOR work at Laval has laid, and is still laying, a sound biological basis for these techniques.

Work in basic sciences tends to be open-ended, but this work was designed to produce concrete results in the period of the ENFOR program 1979 - 1984.

Tangible evidence that this is being done is shown in Tables 27, 28, 29 and 30. These tables illustrate that several Ph.D. and M.Sc. theses have been or are being prepared that are either directly or indirectly attributable to the ENFOR support. This support has also resulted in the preparation of at least eight scientific papers, and several conference

Table 27. Graduate studies associated with the ENFOR P-198 project

M.Sc. THESIS DEPOSITED

- Jobidon, R. 1981. Contribution à l'étude des composés allélopathiques du peuplier baumier (Contribution to the study of allelopathic compounds of balsam poplar)
M. Sc. Ecole des Gradués, Université Laval
(Partly supported by ENFOR).

Ph.D. THESIS IN PERPARATION

- Nesme, Xavier, 1984. Base génétique de la nodulation chez les plantes actinorhiziennes. (Genetic basis of the nodulation of actinorhizal plants).
Partly supported by ENFOR.
- Chaboud, Annie, 1984. Mécanismes biochimiques de la reconnaissance chez l'aulne et les Frankia. (Biochemical mechanisms of the recognition between alder and Frankia). Spin off from ENFOR.
- Younger, Patti 1984. Mechanism of the allelopathic interactions between alder and poplars. (Totally supported by ENFOR).

M.Sc. THESIS IN PREPARATION

- Godbout, Christian, 1982. Détermination et sélection des champignons ectomycorhiziens de l'Alnus crispa et du Populus tremuloides. (Determination and selection of ectomycorrhizal of Alnus crispa and Populus tremuloides). (Totally supported by ENFOR).
- Normand, Philippe. 1982. Isolement, caractérisation et évaluation de diverses souches de Frankia. (Isolation, characterisation and evaluation of different strains of Frankia). (Totally supported by ENFOR).
- Périnet, Pierre, 1982. Multiplication végétative in vitro de deux espèces d'aulne. (Vegetative multiplication in vitro of two alder species). (Partly supported by ENFOR).
- Prégent, G. 1983. Exigences nutritionnelles des aulnes crispé et glutineux. (The nutritional requirements of Alnus crispa and A. glutinosa). (Partly supported by ENFOR).
- Coté, Benoit, 1983. Etude du cycle de l'azote chez l'aulne glutineux à l'aide de la dilution isotopique naturelle et de l'enrichissement à N^{15} . (Study of the nitrogen cycle of Alnus glutinosa with the help of natural isotope dilution and enrichment with N^{15}). (Totally supported by ENFOR).

Table 28. Publications from the ENFOR P-198 program.

-
- Jobidon, R. & J.R. Thibault, 1982. Allelopathic effects of balsam poplar on green alder germination. *Torrey Bot. Club* 4: 413-418 (Partly ENFOR).
- Jobidon, R. & J.R. Thibault, 1982. Allelopathic growth inhibition of nodulated and unnodulated Alnus crispa var. mollis Fern. seedlings by Populus balsamifera. *Amer. J. Bot.* (Accepted for publication).
- Thibault, J.R., J.A. Fortin & W.A. Smirnoff, 1982(?). In vitro allelopathic inhibition of nitrification of balsam poplar and balsam fir. *Amer. J. Bot.* (Accepted for publication). (Spin off from ENFOR).
- Normand, P. & J.A. Fortin, 1982 (?). Comparison of six surface sterilizing agents for aseptic germination of Alnus crispa (Fern.) Push. A note in *Can. J. Bot.* (Submitted for publication). Totally from ENFOR).
- Normand, P., J.A. Fortin & M. Lalonde, 1982 (?). Evaluation of Frankia strains isolated from provenances of two alder species. *Can. J. Microbiol.* (Submitted for publication). Totally from ENFOR).
- Godbout, C. & J.A. Fortin, 1982 (?). Selection of ectomycorrhizal fungi on Alnus crispa. *Can. J. Bot.* (In preparation). (Totally from ENFOR).
- Godbout, C. & J.A. Fortin. 1982 (?). Optimal conditions for ectomycorrhiza formation on Populus tremuloides. *Can. J. Bot.* (In preparation). (Totally from ENFOR).
- Perinet, P. & M. Lalonde. In vitro propagation and nodulation of the actinorhizal host plant Alnus glutinosa (L.) Gaerth. *Plant Science*. (In preparation) (Spin off from ENFOR).

Table 29. Invited conference papers associated with the ENFOR project

-
- Lalonde, M., H.E. Calvert & S. Pine, 1981. Isolation and use of Frankia strains in actinorhizal formation. In: Current Perspective in Nitrogen Fixation. Ed. A.H. Gibson & W.E. Newton. Australian Academy of Science, Canberra. (Spin-off from ENFOR).
- Lalonde, M. 1981. Frankia; on endophytic Nitrogen Fixing Bacterium. The Allen Lectures in Phytobacteriology. University of Wisconsin. (Spin-off from ENFOR).
- Lalonde, M. 1981. Frankia; an unusual symbiotic nitrogen-fixing actinomycete used in forestry; American Society for Microbiology, 81st Annual meeting Symposium. Dallas. (Spin-off from ENFOR).
- Lalonde, M. 1981. Nitrogen-fixing Frankia actinorhizae. Symposium on Rhizobium and Frankia-plant root interactions in Nitrogen fixation. Canadian Society of Microbiologists. Ottawa. (Spin-off from ENFOR).

Table 30. Conference papers with abstracts associated with the ENFOR P-198 project.

-
- Normand, P. & J.A. Fortin, 1981. Isolation d'une souche de Frankia de l'aulne rugueux (Alnus rugosa (Du Roi) Spreng.) ACFAS, 49ième Congrès, Sherbrooke. (Totally supported by ENFOR).
- Jobidon, R. 1981. Interférence allélopathique entre le peuplier baumier et l'aulne crispé. ACFAS, 49ième Congrès, Sherbrooke. (Partly supported by ENFOR).
- Périnet, P., M. Lalonde & J.A. Fortin. 1981. Culture in vitro chez Alnus spp. cals, cellules en suspension et multiplication végétative. ACFAS, 49ième Congrès, Sherbrooke. (Spin-off from ENFOR).
- Perradin, Y. 1981. Contribution à la connaissance phytochimique de l'interférence allélopathique peuplier-aulne. ACFAS, 49ième Congrès, Sherbrooke, (Partly supported by ENFOR).
- Godbout, C. & J.A. Fortin. 1982. Les champignons ectomycorhiziens de l'Alnus crispa et du Populus tremuloides. ACFAS, 50ième Congrès, Montréal. (Totally supported by ENFOR).
- Normand, P., J.A. Fortin & M. Lalonde. Isolation et évaluation de souches de Frankia sur l'Alnus crispa et l'Alnus rugosa. ACFAS, 50ième Congrès, Montréal. (Totally supported by ENFOR).

papers. Most of these are scheduled for completion in the near future, within the ENFOR project period.

Naturally the field experiments will extend beyond the ENFOR contract, although they will yield some results before 1984. It will be necessary to make decisions about the maintenance and future use of these experiments in the near future.

11.2 Intangible productivity

The impact of the support of work on actinorhizal and ectomycorrhizal symbioses at Laval University by ENFOR between 1978 and 1982 has extended far beyond contractual objectives.

In 1979 at the most there were three scientists in Canada with experience, expertise and in-depth knowledge of actinorhizal symbioses in the forestry context.

There were a few more scientists engaged in forest mycorrhizae, and Laval University was already an acknowledged centre of expertise in both endo- and ectomycorrhizae, but not many scientists or foresters were interested.

Alder, with the exception of red alder which has spectacular growth rates in British Columbia, was a despised weed species. Nitrogen fixation, and indeed symbioses and soil biology, were not recognised by foresters as tools that might be used in forestry. This was particularly the case in Canada, although the attitude prevailed over most of the world. There were loci of interest in the USA, but the work was given low priority. Interest had waxed and waned in the agricultural science community for many years.

The energy crisis, the interest in very intensive forestry and the focus on using biomass for fuel stimulated a surge in interest in actinorhizal symbioses in forestry in 1979 - 80, just after the ENFOR work

began at Laval.

Since that time ENFOR support has enabled an internationally recognised centre of expertise on nitrogen-fixation and mycorrhizae in the forestry context to be established at Laval. The ENFOR funds not only supported the contracted work, but acted as seed money that attracted funding from many other sources. The program also attracted first class basic scientists from abroad. Dr. Lalonde, an internationally recognised authority on Frankia returned to Laval from the United States to participate in the work. In addition graduate students from the USA and France have been attracted to Laval.

Most important of all, the program has produced a number of young scientists highly trained in a range of aspects of nitrogen fixation and mycorrhizae in the forestry context. Before 1979 these were sadly lacking. These young, enthusiastic scientists with new ideas will be able to make significant contributions to and good use of the undoubted future opportunities in the field of using nitrogen-fixing and mycorrhizal symbioses in the forestry, and other contexts.

Since the nitrogen fixation program began in forestry, there has been a shift in attitude by many foresters. Alder seed collections are now being sponsored by the International Energy Agency, alder seeds are being banked for future use, alder plants are appearing in field trials in Ontario, Quebec and Alberta, and the forest industry on Vancouver Island has developed a research program on nitrogen fixation.

It is difficult to say how much this shift in attitude is due to the Laval work and the associated work at the federal Petawawa National Forestry Institute, but they have certainly played a part.



This report has been produced through an ENFOR contract
Ce rapport a été produit dans le cadre du programme ENFOR

